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THESIS

A BASELINE ANALYSIS OF COMBAT LOGISTICS FORCE SCHEDULING EFFICIENCY

by

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June 2016

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13. ABSTRACT (maximum 200 words)

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The purpose of this research is to analyze data from Fifth Fleet collected before and after RASP with a goal of establishing a baseline efficiency in Combat Logistics Force (CLF) ship utilization. Supply and demand models were built over the data sets, presenting an interesting view of the disproportion of available commodity available to customers. Efficiencies were compared before and after RASP, resulting in a recommendation that the Fast Combat Support Ship (AOE) be the ship of choice due to better efficiency and cost to deliver commodity to the warship in the Fifth Fleet area of responsibility. The trends from the data were mostly inconclusive, however; as a result, this paper recommends expanding the research years for further data analysis to include 2011, 2012, 2014, and 2016.

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A BASELINE ANALYSIS OF COMBAT LOGISTICS FORCE SCHEDULING EFFICIENCY

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LIST OF ACRONYMS AND ABBREVIATIONS

AOR	area of responsibility
CLF	combat logistics force
CLO	combat logistics officer
CNA	Center for Naval Analysis
CONOPS	concept of operations
CSG	carrier strike group
CTF	combined task force
DFM	diesel fuel marine
DLA	Defense Logistics Agency
DOD	Department of Defense
ISIL	Islamic State of Iraq and the Levant
JP5	jet propulsion fuel, type 5
KTS	nautical miles per hour
LOGSSR	Logistics Support Services Repository
MAD	military advisory board
MSC	Military Sealift Command
NAVSUP	Naval Supply Systems Command
NM	nautical miles
OEW	overall effective work
RAS	replenishment at sea
RASP	replenishment at sea planner
SURFOR	Commander, Naval Surface Forces
T-AKE	dry cargo ammunition ship
T-AO	fleet replenishment oiler
T-AOE	fast combat support ship
THRSG	Theodore Roosevelt Carrier Strike Group
USFF	United States Fleet Forces Command
USNS	United States Naval Ship
USS	United States Ship

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I. INTRODUCTION

A. EARLY REPLENISHMENT AT SEA

Prior to the use of underway replenishment, coaling stations were required to refuel ships far from home. Nineteenth and early twentieth century Britain established a vast network of forward stations and coal ships to ensure operating continuity in their empire. These early warships relied completely upon coal and, as such, coaling stations were a matter of strategic importance. As turn of the twentieth century Navy logistician, C. Theo Vogelgesang stated, “A fleet of battleships is powerful only when its constant mobility is assured, when we are able to guarantee the free and unrestricted movement of that fleet to a given theater of war, and within that area after it has arrived” (Brown, 2010).

The United States, lacking the expansive refueling network of our British counterparts, became interested in underway replenishment around 1900. One of the first experiments, devised by Spencer Miller, took place between the collier *Marcellus* and the battleship *Massachusetts.* In this experiment, a taut suspension cable and a quick release hook connected the ships. Improvements to this system continued for the next decade. In 1917, USS *Maumee* (AO-2) is credited with the first operational underway replenishment under the direction of then Chief Engineer Chester Nimitz. This initial operation successfully transferred around 130 tons of coal over four attempts (Miller, 1900).

B. MODERN REPLENISHMENT AT SEA

Replenishment at sea (RAS) operations have come a long way compared to these early coal predecessors. Today, refueling ships are capable of transferring fuel, cargo and personnel via connected replenishment. This task is typically conducted with ships connected by a tensioned wire at a distance between 140 to 180 feet. Because the ships are connected, it is imperative that speeds are matched perfectly, often to within accuracies involving shaft revolutions, and are conducted at speeds between 10 and 14 knots. Transfer

capacities vary between classes of refueling ship, but modern refueling ships are capable of meeting the demand required for any ship in the U.S. or coalition inventory.

C. MILITARY SEALIFT COMMAND

Military Sealift Command (MSC) is responsible for delivering the commodities needed to sustain American and coalition warships abroad. Located in Norfolk, Virginia, MSC is responsible to U.S. Transportation Command for defense appropriation matters and U.S. Fleet Forces command for Navy-unique matters (Military Sealift Command [MSC], 2015). MSC has five geographic commands that comprise: Atlantic, Pacific, Europe, Middle East, and Far East. Serving in a support role, MSC's main stakeholders include United States Fleet Forces Command (USFF), Surface Forces Command (SURFOR), and the Component Commands. Other stakeholders include Navy Supply Systems Command (NAVSUP), and Defense Logistics Agency (DLA).

1. Combat Logistics Force Concept of Operations for Load Management

Standardization of load management is critical to ensure timely and efficient delivery of necessary logistics to the fleet. Fleet variance, such as weather patterns, customer optempo, political landscape and distance between ports, are challenges logistics officers face. The focal point of theater support is the embedded Combat Logistics Officer (CLO) within each Combined Task Force (CTF) organization. Their role is to ensure optimized supply chain management in their respective Area of Operations (AOR). The Combat Logistics Force (CLF) Business Enterprise Model further provides for standardization, gives direction for load management, and is tailored to specific AOR needs by the AOR Commander (Military Sealift Command [MSC], 2010, p. 41). The CLF fleet primarily consists of Fast Combat Support Ships, Fleet Replenishment Oilers, and Dry Cargo/Ammunition Ships (MSC, 2010).

2. Station Ship vs. Shuttle Ship

Station ships remain on station with the strike group and are capable of keeping pace with the carrier when they transit. During high-tempo operations, time alongside is an important tactical consideration. Station ships are able to deliver all commodities (Diesel Fuel Marine (DFM), Aircraft Fuel (JP5), and cargo) simultaneously, thereby minimizing the overall time of the operation.

Shuttle ships, in contrast, deliver fuel between the station ship and port. Depending on the AOR and the situation, shuttle ships may also be used in the station ship role. This continuous resupply of fuel and cargo by shuttle and station ships allows the strike group to remain on station as long as necessary to achieve its mission goals. Figure 1 depicts the various shuttle and station ships.

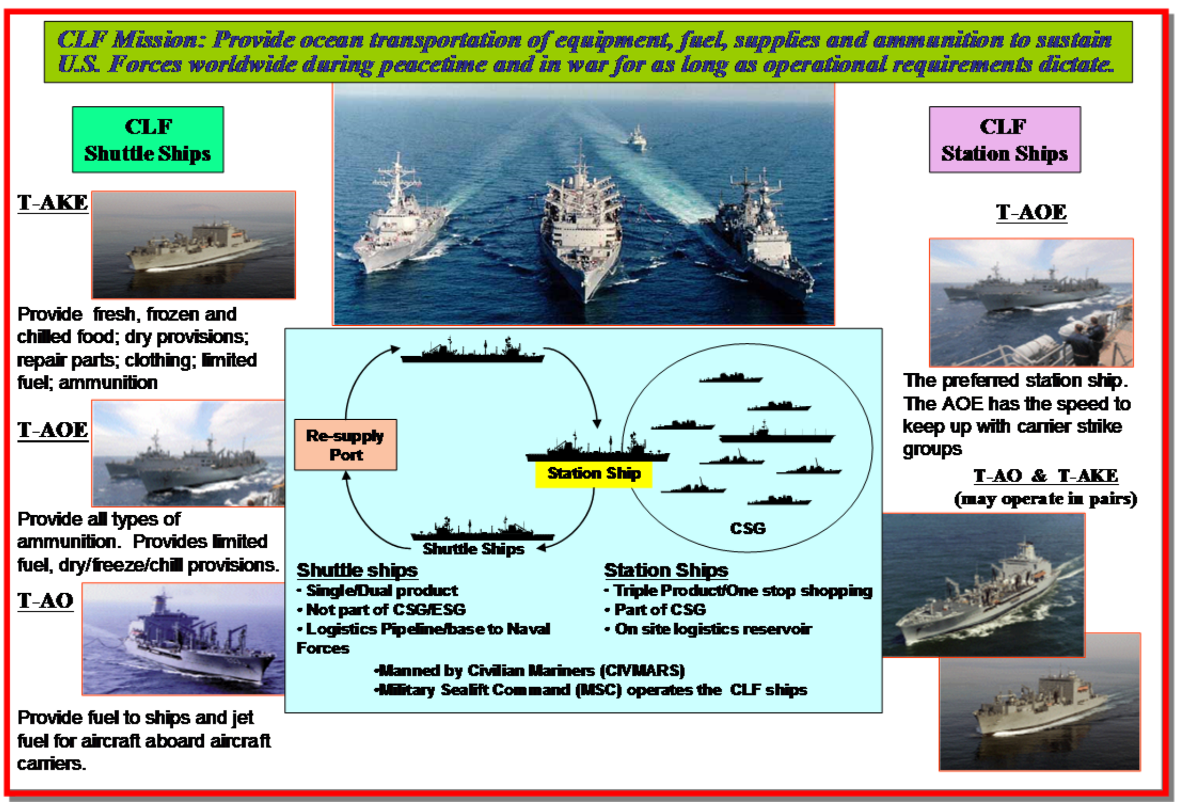


Figure 1. Shuttle vs. Station Ship Concept. Source: Military Sealift Command (MSC), (2010, p. 14).

a. Dry Cargo Ammunition Ships (T-AKE)

The T-AKE is the most versatile ship in the CLF inventory. The T-AKE can be configured for either Ammo or Stores mode depending on the needs of the fleet that it is serving, and is capable of delivering fuel, ammunition or cargo. For the purposes of this study, we will use the T-AKE as a “Stores” configured ship. Typically, the T-AKE will be used as a shuttle ship but is capable of serving in either capacity as will be seen in this study of Fifth Fleet.

b. Fast Combat Support Ships (T-AOE)

The T-AOE is the preferred station ship due to its ability to keep up with the strike group's carrier. It has the ability to provide both fuel and cargo. The T-AOE may also be used as a shuttle ship.

c. Fleet Replenishment Oilers (T-AO)

The T-AO is CLF's primary fuel platform as it has the largest capacity for DFM and JP-5 compared to all of the other CLF assets. The T-AO will primarily serve as a shuttle ship but may deliver supplies directly to customers depending on the AOR. It has no capacity for ammunition and limited cargo capacity.

3. Replenishment at Sea Planner

Prior to 2013, MSC scheduled its CLF assets by hand (or used a spreadsheet) each day. These schedules were prone to error and provided little feedback about the efficiency of delivery assets. Planning supply routes this way led to human errors, which would in turn lead to higher fuel costs than necessary. As a result of these errors CLF ships were required to operate at faster speeds to make engagements. The Replenishment at Sea Planner (RASP) program was a potential answer to this issue. RASP was developed under the auspices of Military Sealift Command and Office of Naval Research by Naval Postgraduate School and is a tool that Fleet staff can use to develop more fuel-efficient daily tasking for CLF ships in an operational theater. It is a decision support tool that aids CLF vessel schedulers in the planning, assessing, and execution of various

courses of action by CLF vessels to support combat customers. It is underpinned by sophisticated operations research optimization tools that allow the most efficient shipping routes to be selected. RASP also allows for contingency routes to be created in the event that changes may be needed. RASP was placed into operation in 2013 in the Fifth Fleet AOR.

D. PURPOSE

Today's political and fiscal environment dictates responsible and efficient use of the resources entrusted to government agencies. The 2016 President's Budget showed an approximately 20% decrease from 2015 in Operations and Maintenance Funding from which the Navy pays its fuel costs (Operation and Maintenance Programs [O-1] Revolving and Management Funds [O-1] Revolving and Management Funds [RF-1], 2016). Fuel costs account for an enormous percentage of the Department of the Navy's annual budget at 11% (Lengyel, 2007).

There are some long-term options available to help reduce fuel costs through upgrades to ship engineering plants and the use of special paints designed to prevent drag through the water. The capital cost associated with these ideas is often expensive and may take years to implement. Also, the effectiveness of some measures may not be apparent without time consuming and extensive analysis of data that is not readily available. With decreasing budgets and deployed units remaining at their current optempo, increased efficiency is needed now. Implementing changes to how the Navy delivers its fuel and cargo and specifically to how MSC schedules its CLF resources can potentially have an immediate impact by increasing effectiveness while saving fuel costs.

This purpose of this study is to establish a baseline understanding of what the historical efficiency of CLF assets has been in the Fifth Fleet AOR. Fifth Fleet was chosen due to the historically high amount of ship deployments to the area, to help ease calculations due to the few major ports that MSC uses, and because

RASP has been in use there for several years. Also, warships deployed to the Fifth Fleet AOR typically receive the majority of their fuel and supplies through RAS as opposed to receiving resources by pulling into port. Ideally, general concepts derived from this analysis may be applied to other AORs. Once a baseline has been established, it will then be compared to data retrieved from RASP. The comparison data will then be used to help understand and make recommendations for increasing scheduling efficiency of Fifth Fleet CLF assets and ultimately fuel cost saving measures to the Department of Defense.

II. LITERATURE REVIEW

This chapter provides background information from related literature and studies. It begins with a broad understanding of the operational ideas the U.S. government uses when loading logistics ships. Next, the focus shifts to challenges that the government is encountering in meeting the increasing demand of operational warships and the potential impact of an excessive fuel consumption and an over-reliance on foreign fuel. Lastly, it uses literature to help define important matrices needed to understand efficiency in logistics ships.

A. COMBAT LOGISTICS FORCE (CLF) LOAD MANAGEMENT CONCEPT OF OPERATIONS.

As previously mentioned, MSC is responsible for the replenishment of warships while at sea and it accomplishes this through its CLF. The Concept of Operations (CONOPS) was issued in March of 2010 with the intent of standardizing load management policy. The ultimate goal is to provide the maximum operational support to warships with the appropriate commodity at the right time.

1. Support and Sustainment Cycle

Planning, execution, deployment and lessons learned comprise the four phases of the operation cycle. Planning will include pre-deployment conferences where stakeholders share needs and the initial load-out decisions for the deployment are made. The execution phase includes load-out of the vessel as previously determined and the transit to the operating area. The deployment phase refers to the warship deployment in the operating area as opposed to warship's logistic supporting asset. CLF platform deployments are from one to four years in forward operating areas. The events conducted during the deployment phase may include (MSC, 2010, p. 15):

- Top off re-supply at first available re-supply port
- Conduct Shuttle Ship operations

- Conduct "Race track" Underway Replenishment (UNREP) and Replenishment (RAS) events
- Provide Embassy Support
- Load/unload Fleet freight as required

2. Pallet Load Management

While CLF assets carry a wide range of items to support fleet combat ships, the depth of those items depends upon the AOR that the ships are operating in as mission requirements change significantly between geographic areas. Other factors may contribute to the load out of the CLF asset. These include CTF operational requirements, ship Master's safety concerns with respect to weather and stability and the ships schedule (MSC, 2010, p. 23). Figure 2 is a depiction of the general pallet load-out capacity by class. The values in this table were used as assumptions for this study's supply calculations.

	T-AKE (Stores Mode)	T-AKE (Ammo Mode)	T-AOE	T-AO
DRY	*3266	*984	*325	100
Freeze / Chill	*1134	*1134	*400	128
HULL	285	285	103	103
Deck Load	NA	NA	100	100
Ammo	**216690 FT3	**432740 FT3	**166023 FT3	0
Fleet Freight	~tbd	~tbd	~tbd	~tbd
FHA	45	45	NA	NA
Total Pallet Positions	4730	2448	928	431

* Pallets are double stacked in most of the storerooms.
** No Compatibility / NEW issues

Figure 2. CLF Total Pallet Position Capacity. Source: MSC (2010, p. 24).

3. Fuel Load Management

CLF assets normally carry Diesel Fuel Marine (DFM) and JP5 (Turbine Fuel, Aviation, High Flash Type with FSII, MIL-DTL-5624 Series) for delivery to warships (MSC, 2010, p. 27). Seven-inch hoses are normally used to transfer fuel with the exception of the T-AKE. The T-AKE will use a 2.5-inch hose to pump

JP-5 which limits its ability to refuel aircraft carriers due to the vast quantities of JP-5 required. Nominal CLF ship fuel capacities are shown in Table 1. The values in this table were used as assumptions for this study's supply calculations.

Table 1. CLF Platform Fuel Capacity. Source: Military Sealift Command (MSC), 2010.

	T-AKE		T-AOE		T-AO	
	Capacity	**Pump Rate**	**Capacity**	**Pump Rate**	**Capacity**	**Pump Rate**
DFM	733K gals	3K gpm	4,010K gals	3K gpm	4,500K gals	3K gpm
JP-5	370K gals	237 gpm	2,655K gals	3K gpm	3,000K gals	3K gpm

4. Total Asset Visibility

Enterprise resource management is the standard for civilian corporations. Automatic shipping and order of supplies ensures minimum bureaucracy and more efficient use of resources. MSC implements this business model and has employed information technology systems ashore to serve as a catalyst to this process. Using these systems, CLF schedulers have visibility of all material aboard ship. Understanding current operations and historical demand, schedulers are able to plan ahead of needed orders and ensure CLF ships are available to meet the underway replenishment demand. This capability serves as an invaluable tool when faced with multiple ship demands (MSC, 2010, p. 42).

B. CARGO SHIPS ROUTING AND SCHEDULING: SURVEY OF MODELS AND PROBLEMS

David Ronen's essay on commercial carrier management operations suggests that the shipping of cargo "costs thousands of dollars a day and that significant savings can be achieved by proper fleet routing and scheduling" (1983, p. 119). It is important to note that Ronen's essay is over 30 years old and costs likely have increased. As the world population continues to rise, international trade will continue to play an important economic role in world policy

and politics. International shipping is the cornerstone of successful trade. Approximately 90% of the world trade is accomplished through shipping and without it, the import and export of goods at its current level would not be possible. There has been much research in the operational management of shipping but it has mainly been devoted to land and air shipping with little attention being given to shipping via sea transport. The author suggests that there may be several reasons for this to include low visibility (truck carry most of the load in the United States), ship scheduling is less structured than standard vehicle scheduling, there is much more uncertainty in ship scheduling to include everything from market volatility to weather, and there is a long tradition in ocean shipping that makes the overall industry less open to new ideas (1983, p. 119).

The three general modes of operation in shipping are liner, tramp and industrial. These are not well defined or mutually exclusive and several modes may happen at the same time (1983, p. 120).

Tramp resembles taxi cab services where ships go where cargo is available. The cargo is usually a whole shipload with a single origin and one or two destinations. Liner is usually operating on closed routes with no voyage defined origin and destination because they load and unload in each port and depends on the quality of service to include frequency, transit time, and reliability. Ronen suggests that major modelling methods for liner must rely on simulation and heuristic decision rules (1983, p. 123). Industrial shipping is similar to private truck fleet operations. The owner of the cargo controls the fleet of ships and assures transportation of the organization's cargo and reduced costs.

For our purposes, it would appear that the industrial operations model best fits with the MSC's business model and the goals of this research. Assuming a given fleet size, linear programming was used to minimize the total ballast (empty) leg of a voyage and therefore minimized overall costs (1983, p. 123). Ronen suggested, in 1983, that computerized models would help to minimize the complexity of scheduling operations. This has proven true with MSC as it attempts to increase efficiency with the RASP program. Furthermore, the author

gives practical advice such as avoiding unnecessary port costs by not pulling into ports over the weekend when cargo handling crews are not working.

C. MARITIME ECONOMICS

Maritime Economics, 3rd Edition by Martin Stopford explains the organization of the world shipping markets and describes the influence of shipping on world markets through history, the organization of sea transport and the determination of prices and freight rates. This study is particularly interested in the development of his supply and demand models and calculation of freight rates. The author describes ten variables in the shipping market model:

- The world economy
- Seaborne commodity trades
- Average haul
- Random shocks
- Transport costs
- World fleet
- Fleet productivity
- Shipbuilding production
- Scrapping and losses
- Freight revenue (2009, p. 136)

The first five variables define demand while the last five describe the impact upon supply. Stopford defines final demand as the tonnage of cargo multiplied by average haul and states that efficiency should be included in the supply portion of the function (2009, p. 137). As productivity and efficiency are key to this research, the author's definition of productivity are also important. He states that productivity is a function of four factors to include speed, port time, deadweight utilization and loaded days at sea (2009, p. 155).

D. FUELING THE BALANCE

"Fueling the Balance: A Defense Energy Strategy Primer" by Jerry Warner and P. W. Singer argues that the current energy crisis is much more than an environmental catastrophe but an urgent issue for strategic national security. The authors explore the relationship between U.S. petroleum based tactical operations and how the costs of fuel affect Department of Defense (DOD) planners and their budgets. They argue, "Their (fuel costs) availability and cost now significantly impact military budgets, combat mission execution, institutional capabilities, and, by implication, our national security" (Warner, 2008, p. 3). They address concerns that only a small amount of the budgeted fuel is consumed by actual combat vehicles but instead is mostly used to transport and deliver the fuel. This gross inefficiency is likened to Civil War era supply trains where half of the mule drawn wagons were used to transport hay to feed the animals (Warner, 2008, p. 4).

The report considers the opportunity cost associated with both the protection of these valuable commodities and the loss in the budget that may have been better spent. The authors acknowledge that some action has been put into motion but argue that current efforts are not enough to solve the issue as demand continues to rise. The report also acknowledges the challenges placed on policy makers and DOD budgets by explaining the impact on price fluctuations in fuel. They say, "Overall, each and every $10 increase in the cost of a barrel of oil increases the price of DOD operations by $1.3 billion. To put this into context, each $10 price increase is equivalent to a loss of almost the entire U.S. Marine Corps procurement budget" (Warner, 2008, p. 5). Warner and Singer recommend streamlining DOD energy management, investment in new technologies, and providing needed tools and resources to help establish organization culture change.

E. POWERING AMERICA'S DEFENSE

"Powering America's Defense: Energy and the Risks to National Security" was released by the Center for Naval Analyses' (CNA) Military Advisory Board (MAD) in 2009. The report is a build on the original 2007 edition that explores energy choices the nation can make to enhance overall national security. It argues that U.S. dependence on fossil fuel undermines economic stability and weakens U.S. international political leverage with otherwise insignificant state actors. The CNA sets forth the following roadmap of priorities to better energy security:

- Priority 1: Energy security and climate change goals should be clearly integrated into national security and military planning processes
- Priority 2: DOD should design and deploy systems to reduce the burden that inefficient energy use places on our troops as they engage overseas
- Priority 3: DOD should understand its use of energy at all levels of operations. DOD should know its carbon footprint
- Priority 4: DOD should transform its use of energy at installations through aggressive pursuit of energy efficiency, smart grid technologies, and electrification of its vehicle fleet
- Priority 5: DOD should expand the adoption of distributed and renewable energy generation at its installations
- Priority 6: DOD should transform its long-term operational energy posture through investments in low-carbon liquid fuels that satisfy military performance requirements (2009, p. ix)

This report strikes at the core of the need of a clear understanding of how the choices operators and, in the case of this study, schedulers make can have direct strategic impacts. The inefficient use of scarce resources creates a

domino-like effect at all levels of our government and ultimately to its primary stakeholders, the taxpayer. The CNA reports that there are high opportunity costs associated with over-allocating funds to cover fuel costs as some other programs may become under-funded (CNA, p. 23). These potential disruptions may be the cause for a lack of training or procurement.

F. DEPARTMENT OF DEFENSE ENERGY STRATEGY: TEACHING AN OLD DOG NEW TRICKS

Colonel Lengyel's paper portrays the U.S. government as over-reliant on fossil fuels and suggests that a potential fuel crisis is looming. Lengyel (2007, p. 7) states, “Energy is the life-blood of the US economy and dependence on imported energy is a looming national crisis.” First, he argues that energy use is the key enabler of U.S. military combat power and that the DOD must recognize the problem from a military perspective (2007, p. 8). His next argument is that the DOD must recognize this military vulnerability and that energy usage must be managed much like intelligence or logistics. Lastly, he recommends a long-term energy strategy and an energy chain of command (2007, p. 10).

G. RUNNING AHEAD: FOUR YEAR PLAN

Running ahead is a paper by Mr. Adrian Zavala who works in a consulting capacity for MSC Far East. The ideas presented in “Running Ahead: Four Year Plan” represent the basis for the methodology used in my research and analysis. This paper was written as an internal document for MSC and specifically modelled CLF operations. Zavala defines two basic provider models to support customers: high priority and pure logistics. In high priority, the goal is to ensure maximum operational capability for the customers, regardless of cost or efficiency. This is in contrast to the pure logistics model where efficiency is the priority and it is in this mode that costs savings can be achieved. The paper lays out a plan for each of the four years and suggests an over-arching shift to a culture that is consistent with efficiency and cost savings. Each member of the

organization has to understand the vision and direction that leadership is directing.

Understanding the process of data collection, storage, dissemination and use is critical to making improvements in the process. Zavala defines “six fundamental objectives while maintaining cognizance of all forces which act upon technical hardware of the vessel” (2016, p. 5). These objectives are:

- Assess Demand
- Assess Supply
- Maximize cargo loading per voyage
- Minimize non-work periods, subject to demand
- Minimize the fuel consumption per non-working period, subject supply and demand balance
- Minimize Gallons per Tonne Mile per voyage

By assessing each voyage and then putting all voyages within a defined period together, a picture of overall efficiency may be obtained. Figures 3 and 4 depict the metrics used to assess demand and supply.

Figure 3. Demand: Required Information. Source: Zavala (2016).

Type Vessel	Class Vessel	Pallets Capacity	Fuel Barrel Capacity	Total M^3 Capacity	Minimum Speed (knots)	Maximum Speed (knots)
Dry Cargo/Ammunition	*T-AKE	4730	26262	11270	9	22
Fleet Replenishment Oiler	T-AO	431	178571	29037	7	22
Fast Combat Support	T-AOE	928	158690	26622	4	30

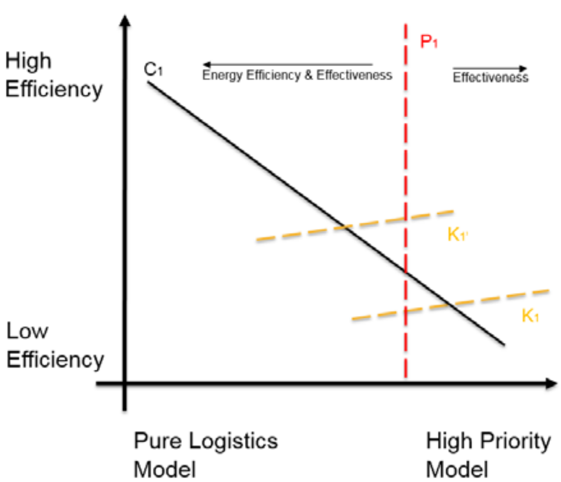
*Capacities for AKE in 'Stores' Mode

Assessing Potential Supply: Required Information

- Total Carrying Capacity of the vessel
- Minimum and Maximum Speeds
- Defined assessment period or maximum endurance of vessel
- Vessel Utilization: defined as the percentage of cargo carrying capacity used in any given voyage
- Voyage Utilization: defined as the ratio of work periods to non-work periods for the assessment period, typically on voyage basis. Can be broken down further into categories of at-sea or in port.

Figure 4. Supply: Required Information. Source: Zavala, 2016

Zavala argues that data drives the process of attaining better efficiency but all data is not relevant and in order to be relevant it must answer two questions: “From what baseline year are we assessing?” and “Is relevant data being captured prior to our baseline year?” (2016, p. 9). Figure 5 depicts the linear efficiency function.



Paradigm Shifts – Efficiency & Effectiveness

- The linear function of C1 is reflective of known voyage models and normalized demand of the customer base.
- K1 Δ K1’ reflects potential improvements attainable by increased information, speed of communication and reduction (or collaring) of unknown information.
- P1 represents the costs to support a customer base at Fleet policy thresholds. The relationship between threshold levels and effects on high priority scheduling are unknown.

Figure 5. Efficiency vs. Logistics Models. Source: Zavala, 2016

III. DATA, MODEL DEVELOPMENT AND METHODOLOGY

This chapter will describe the data sets used, to include why specific data sets were chosen, limitations encountered with these data sets, and external factors that may have contributed to later results. Complete variable descriptions, construction, and an explanation of assumptions are also included.

A. DATA DEVELOPMENT

The development of the data to include explanations of military and political operations during the years of consideration will be described in the following sections.

1. 2009 and 2010 Pre-RASP Data Sets

A major purpose of this study is to establish a baseline for comparison of pre-RASP versus post-RASP scheduling efficiencies. The 2009 and 2010 scheduling years for the Fifth Fleet are close enough to the 2013 launch of RASP to still be relevant for this comparison. During 2009, Operations Wolf Pursuit, New Hope, Ninewa Resolve, and Legion Pursuit were taking place in Iraq in support of coalition forces and the Iraqi War (Understanding War, 2010). As such, the USS Theodore Roosevelt Carrier Strike Group (THRSG) conducted flight operations in support of ground forces. Likewise, operations in Afghanistan continued to require air support which was supplied from the THRSG. Later in 2009, as troops were starting to be withdrawn from Iraq and focus shifted to Afghanistan, fewer flights were required from the carrier strike groups (CSG) in the Fifth Fleet AOR (CNN, 2016). The year 2010 showed continued support of operations in Afghanistan support by CSGs.

This difference in operations provides for an interesting dynamic in required demand. For the purposes of this study, demand is defined as the actual cubic meters of commodity (DFM, JP5, or pallets of cargo) transferred from MSC supply ships to operational warships via replenishment at sea. Figure 6 depicts

calendar year 2009 quarter one required demand for dual operations in Iraq and Afghanistan.

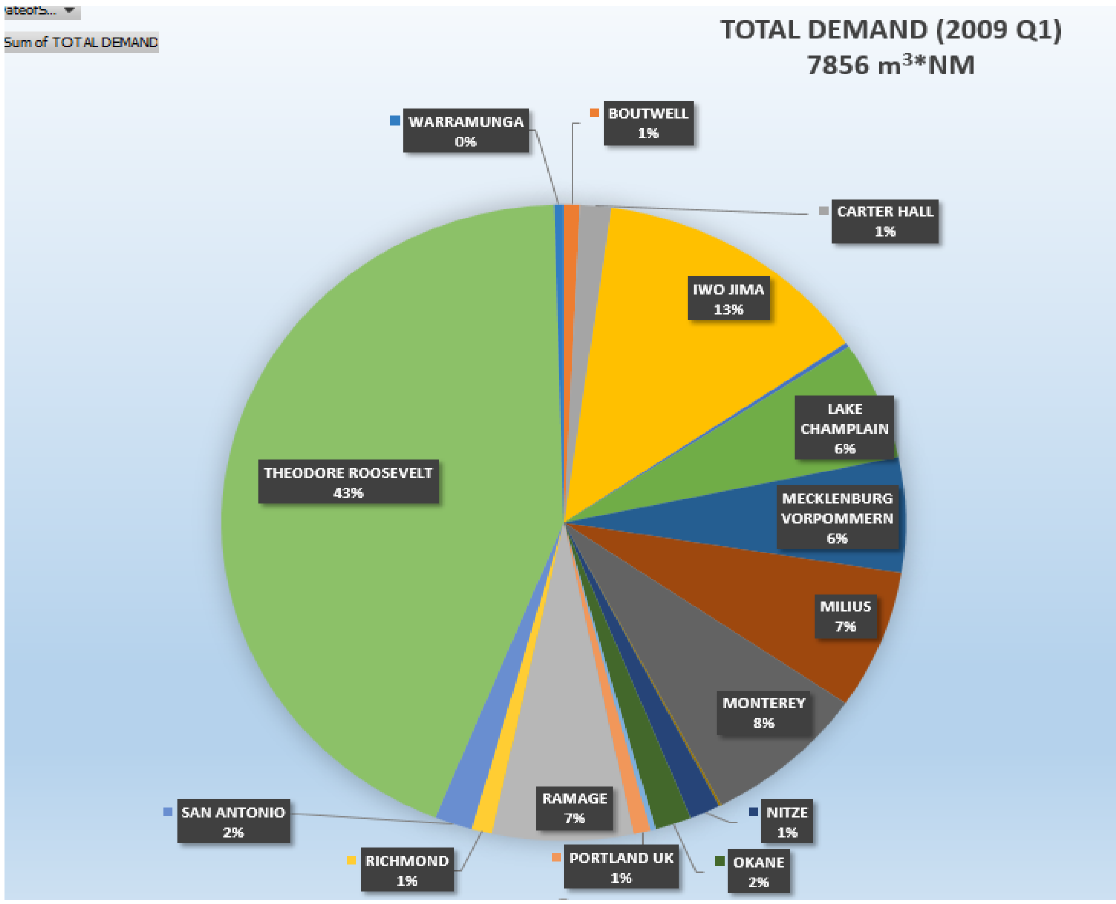


Figure 6. Fifth Fleet AOR CY2009Q1 Total Demand

The types of operations shift in 2010 requiring less air support from U.S. aircraft carriers and more coalition based freedom of navigation and power projection type missions. This is apparent from required demand and is depicted in Figure 7. Of note, 2011 was also initially analyzed by this study but was omitted due to time restrictions.

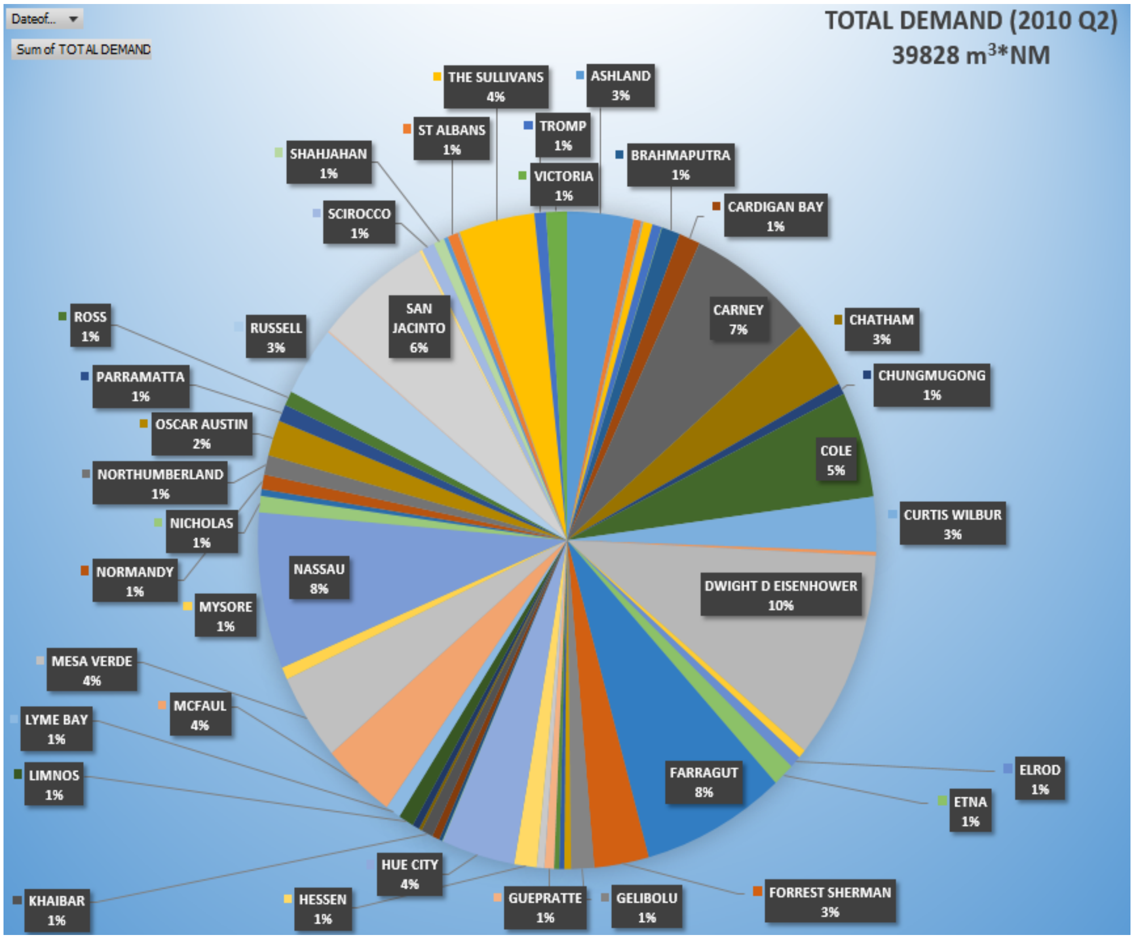


Figure 7. Fifth Fleet AOR CY2010 Q2 Total Demand

2. 2013 and 2015 Post-RASP Data Sets

The 2013 and 2015 data sets were used because they are post-RASP initialization. Operations in the Fifth Fleet AOR are similar to those observed in 2009 and 2010 with the focus now on bombing operations from U.S. aircraft carriers against the Islamic State of Iraq and the Levant (ISIL). This produces a hybrid type of demand where aircraft fuel increases the proportion of use by aircraft carriers while coalition freedom of navigation is still taking place. Figure 8 depicts a sample of 2013 and 2015 demand.

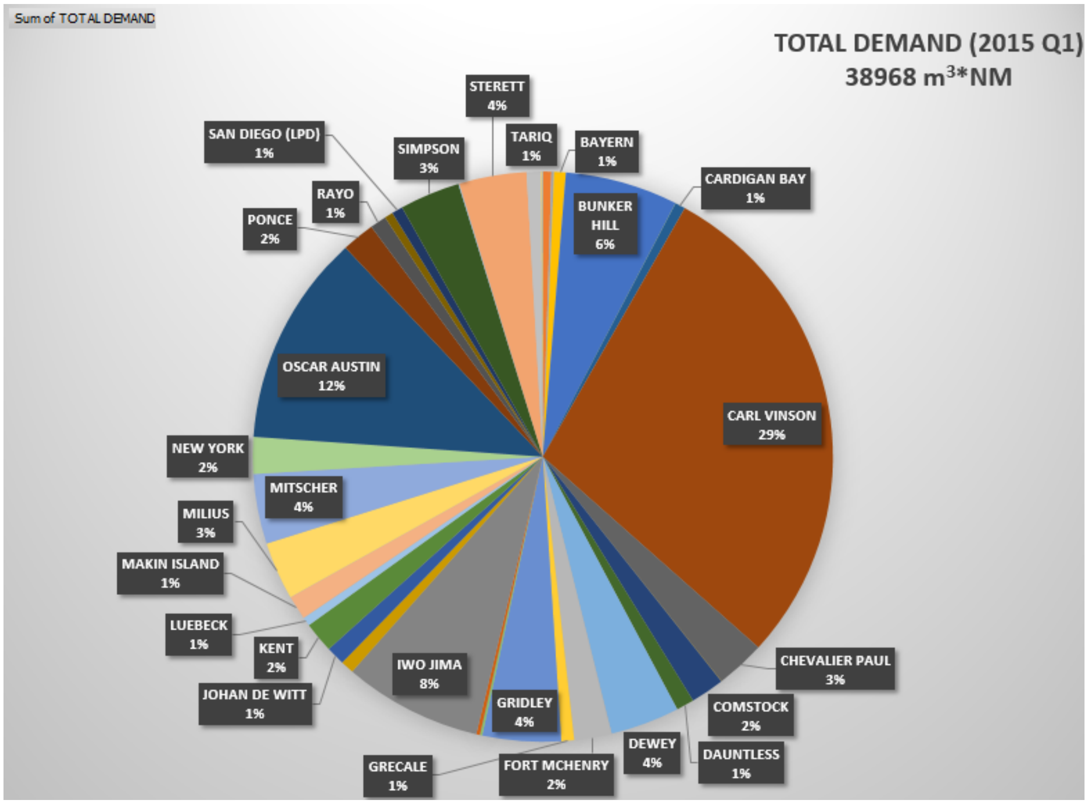


Figure 8. Fifth Fleet AOR CY2015 Q1 Total Demand

B. DATA LIMITATIONS

Prior to RASP, there were several opportunities for "bad" information to make its way into the overall data. Times, dates, and quantity of commodities transferred or received were based on reports submitted to MSC. These reports relied on both the accuracy of the ship making the report and the person entering the data into the data storage system.

To build the model, it was necessary to pull each day's schedule (in excel file format) for the time periods analyzed in 2009 and 2010 and then transfer that data into a new Excel workbook. Because the schedule was built daily by hand prior to RASP, any changes that were not captured in that day's schedule were not available to transfer into the overall database and analysis.

While some comments about commodity type and general operation are available, the reasons for scheduling a certain MSC asset for a replenishment at

sea or a reposition to another port remain with the scheduler alone and are not available for my analysis. An understanding of the train of thought of the person making the schedule would help with the overall understanding of efficiency percentages.

Coalition ships, both warships and supply vessels, play a major part in operations in the Fifth Fleet AOR and add significantly to both supply and demand models. Limitations in the calculation of voyage utilization, vessel utilization, overall effective work, and freight rates were encountered in relation to U.S. coalition partners. While M.port data is available for many of their voyages, port calls to restock supply are not available making my current models ineffective. Definitions of these metrics follow in Section C of this chapter.

C. EXPLANATION OF VARIABLES AND MODEL DEVELOPMENT

1. M.Port

The latitudes and longitudes of replenishment at sea locations are considered classified. To prevent an over classification of this study, M.port values were developed to apply distances in determining efficiency. M.port is the closest distance between a major port and a replenishment at sea area. The major ports in consideration for the Fifth Fleet AOR are Jebel Ali, Fujairah and Djibouti. Table 2 shows an example of how M.port data was applied to determine the distances required for this study.

Table 2. Example 1: Using M.port to Determine the Distances between RAS Events

DateofSvc	Ship_Port_Serviced	M.Port	XFR DFM M^3 CONVERTED	XFR JP5 M^3 CONVERTED	TOT XFR PALLETS M^3 CONVERTED	TOTAL XFR M^3	DISTANCE TRAVELED WORK	DISTANCE TRAVELED NON-WORK	TOTAL VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK
1/9/2015	FUJAIRAH	0	0	0	95							
1/10/2015	HURRICANE	130	17	0	0		130					
1/11/2015	DEWEY	130	477	6	36							
1/13/2015	GRIDLEY	130	1003	35	39							
2/1/2015	THUNDERBOLT	130	27	0	0							
2/2/2015	DEWEY	130	374	12	0							
2/4/2015	CARL VINSON	374	0	2695	0		599					
2/4/2015	DAUNTLESS	374	257	0	0							
2/4/2015	BUNKER HILL	374	498	10	0							
			2651	2759	75	5486	729	374	1103	19%	66%	12%
2/5/2015	JEBEL ALI	0	0	0	0							

In example 1:

- The CLF asset leaves Fujairah (FUJ) on its voyage.
- The first RAS event is 130 NM away from FUJ.
- The CLF asset leaves the first RAS event en route to the second RAS event.
- The distance between RAS event one and two is 599 NM.
- RAS event two is 374 NM away from Jebel Ali (JEB).
- The total distance traveled for this voyage is the sum of distances traveled on the voyage from FUJ until the assets return to port in JEB (1103 NM).

Using this process, I used M.port to calculate the distances for all voyages by CLF ships in the Fifth Fleet AOR for the years analyzed.

2. Demand and Total Demand

For this study, demand is defined as the total amount of commodities, in cubic meters, transferred from a provider asset to an operational warship multiplied by the M.Port for that operational warship for each replenishment at sea event. The total demand is the summation of all demand during the time frames being analyzed. There are three commodities considered:

- Diesel Fuel Marine (DFM): This is the fuel used by warships for propulsion and miscellaneous services.
- Turbine Fuel, Aviation, High Flash Type with FSII, MIL-DTL-5624 Series (JP-5): This is the fuel used by aircraft
- Pallets: This includes ordinance, stores, and all cargo needed for warship operations.

The commodity data was sourced from the Center for Naval Analyses' raw data for the Combat Logistics Force quarterly report. The initial data was reported in gallons and pallets transferred or received so conversions of .00379 gal/m^3 and 1.5 pallets/m^3 were used for conformity.

3. Supply and Total Supply

Supply, for this study, is defined as the product of the total cubic meter capacity of each provider vessel and the speed in knots which they are capable of attaining for the period they are available in theater, less the time they are unavailable during the time frames being analyzed. Total supply is the summation of all provider vessel's supply during the period being analyzed.

For example: A provider asset has a total carrying capacity of 29,037 m^3, a maximum speed of 20 knots, and is in theater 30 days. Therefore: 29,037 m^3 * 20 kts * 24 hours * 30 days = 418,132,800 m^3 * NM. Any time spent conducting maintenance or in yard periods would be subtracted from the total available days. For this study, a speed of 14 knots was used as the primary voyage speed used by CLF assets for later analysis of efficiency and freight rates. Using the minimum and maximum speeds of CLF assets allows for an analysis of minimum and maximum supply available during the time periods analyzed.

4. Overall Effective Work (Efficiency)

The overall effective work done by a CLF asset over a voyage is the product of how much of the possible capacity was utilized and how much of the total voyage distance travelled was used for actual work. Working distance travelled is the distanced travelled by the CLF asset to deliver goods at a RAS event. This is also known as the laden leg of the voyage. The non-working distance is the distance required to return to port and this is known as the ballast leg of the voyage.

In Example 1, the working distance was the distance from FUJ to RAS 1 and then the distance from RAS 1 to RAS 2 (729 NM). The distance to return to port in JEB of 374 NM counts as the non-working distance. This ratio of working and non-working legs of a voyage make up voyage utilization. In this example the voyage utilization would be:

729 NM / (729 + 374) NM = 66% efficiency

The other part of overall effective work is the vessel utilization. In Example 1, the CLF asset delivered a total of 5,486 m^3 of commodities to its customers. The total capacity for this vessel is 29,037 m^3. Vessel utilization is the ratio of these values. Therefore, vessel utilization for this voyage is 5,486 m3 / 29,037 m3 = 19%. The overall effective work would be 19% * 66% = 12%.

5. Freight Rates

Freight rates take the efficiency process one step further. The goal of efficient military logistics operations is to ensure 100% operational capability of warships while saving tax payers as much as possible. The freight rate for a voyage is defined as the total amount of commodity, in m3, transferred divided by the total cost of the voyage. Total voyage cost is composed of transit costs (cost of fuel to transit the CLF asset, wages of employees, stores consumed, etc.) and port costs (cost of daily pier services, cost of tugs, costs to anchor, etc.).

Transit costs for this study assume the provider asset transits at 14 kts and burns 16,750 gallons of fuel per day at $1.97 per gallon. Port costs vary from port to port and standard daily rates were derived from Logistics Support Services Repository (LogSSR) historical data. Table 3 depicts the calculation of freight costs using the data from Example 1.

D. METHODOLOGY

In order to compare pre-RASP versus post-RASP efficiencies, the overall effective work metric was modelled quarter over quarter, year over year, and class of ship over class of ship. The standard deviation of the cumulative percentages was then calculated for both data sets and for the above metrics. It was important to understand which factor in the overall effective work equation was driving the results. Voyage utilization and vessel utilization were modelled quarter over quarter, year over year, and class of ship over class of ship. Standard deviations for these metrics were then calculated and compared to the respective results.

Table 3. Freight Rate Calculation.

Ship_Port_Serviced	TOTAL XFR M^3	DISTANCE TRAVELED WORK	DISTANCE TRAVELED NON-WORK	TOTAL VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK	PORT COSTS	DAYS @ SEA	TOTAL FUEL CONSUMED (GAL)	VOYAGE COSTS (14 KNTS)	TOTAL COSTS	FREIGHT COSTS (PER M^3)
JEBEL ALI													
JEBEL ALI													
JEBEL ALI													
JEBEL ALI													
COMSTOCK		566											
MAKIN ISLAND													
THUNDERBOLT													
MAUI		267											
	1982	833	130	963	7%	87%	6%	$ 12,975	6	100500	$ 197,985	$ 210,960	$ 106
FUJAIRAH													

Next, freight rates were compared over pre-RASP versus post-RASP data sets. These rates were modelled quarter over quarter, year over year, and class over class. Finally, the standard deviation of the rates was calculated and compared to the data. Tables 4 through 10 depict the data sets used to model the statistical analysis.

Last, total supply and demand was calculated for each period analyzed. Supply was calculated through each month by summing the products of total commodity capacity, days in theater, and a speed of 14 kts. The minimum and maximum theoretical supply was collared by using the minimum and maximum speeds of the CLF asset. The total supply of commodity in cubic meters was reduced by a factor of 10,000 to allow for a more digestible ratio when compared to demand. Total demand was calculated by summing the demand by each operational vessel in the Fifth Fleet AOR during 2009, 2010, 2013, and 2015. Figures 9 and 10 depicts the relationship between supply and demand for both pre-RASP and post-RASP periods.

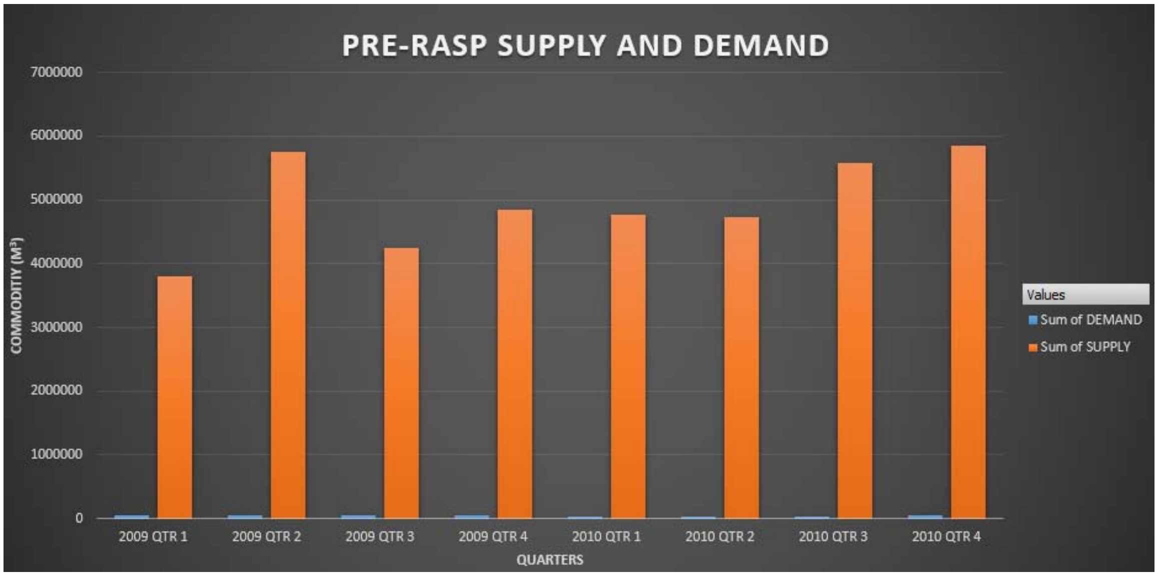


Figure 9. Pre-Rasp Supply and Demand

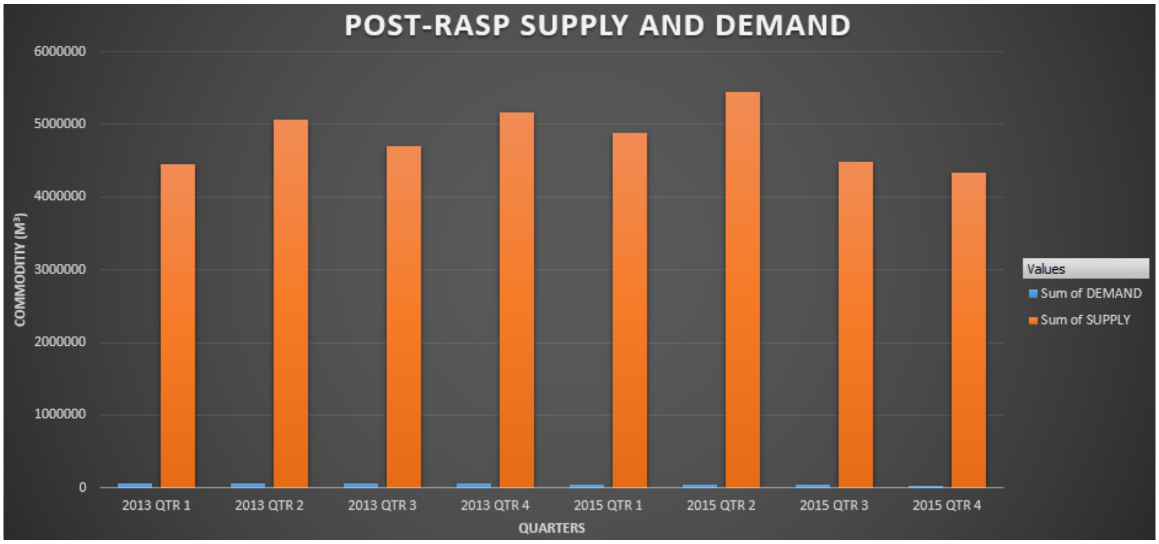


Figure 10. Post-RASP Supply and Demand

Table 4. Pre-RASP Efficiency Data Set

Year	Quarter	HUMPHREYS	LENTHALL	DIEHL	GRUMMAN	KANAWHA	PECOS	BIG HORN	TIPPECANOE	PATUXENT	YUKON	LARAMIE	RAPPAHANNOCK	LEWIS AND CLARK	SACAGAWEA	PEARY	EARHART	SUPPLY	BRIDGE	RAINIER	2009 TOTALS	2010 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2009 Q1	1						10%	11%	17%					12%	3%			12%			11%	
2009 Q2	2			9%	15%		8%							24%	4%						12%	
2009 Q3	3		17%	5%	7%			8%												10%	9%	
2009 Q4	4		3%			28%		14%									16%		10%		14%	
2010 Q1	1					10%	5%		10%							17%	2%	16%				10%
2010 Q2	2								15%	17%	23%	17%				13%		8%				16%
2010 Q3	3	5%	18%				7%				22%	19%		13%		25%						16%
2010 Q4	4	6%		4%			7%		19%		8%			24%			22%			10%		13%
CLASS AVERAGE		12%												13%				11%				
CLASS STD DEV		5%												7%				1%				
EFFICIENCY TOTALS		6%	13%	6%	11%	19%	5%	8%	11%	15%	17%	18%	18%	18%	4%	18%	13%	12%	10%	10%	12%	13%
PRE-RASP EFFICIENCY TOTAL		12%																				
STD DEV		5%																			2%	3%

Table 5. Post-RASP Efficiency Data Set

Year	Quarter	HUMPHREYS	DIEHL	ERICSSON	PECOS	TIPPECANOE	PATUXENT	LARAMIE	EVERS	SHEPARD	BYRD	BRASHEAR	DREW	CHAVEZ	BRIDGE	ARCTIC	RAINIER	2013 TOTALS	2015 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2013 Q1	QTR 1	8%	7%				4%	4%		13%					11%			8%	
2013 Q2	QTR 2	7%	15%					11%	16%	15%					9%		13%	12%	
2013 Q3	QTR 3	3%				9%	23%			11%				52%		16%	73%	27%	
2013 Q4	QTR 4				7%		1%	15%		6%				9%		14%	76%	18%	
2015 Q1	1	5%	8%				6%	3%		7%			11%				14%		8%
2015 Q2	2	12%	11%	6%				8%		14%		54%	12%			34%	9%		18%
2015 Q3	3	6%		4%			18%			10%		17%				13%			11%
2015 Q4	4	0%			7%		6%	4%		8%	13%	13%				17%			9%
CLASS AVERAGE		8%							18%						22%				
CLASS STD DEV		2%							9%						14%				
EFFICIENCY TOTALS		6%	10%	5%	7%	9%	10%	8%	16%	11%	13%	28%	12%	31%	10%	19%	37%	16%	11%
POST-RASP EFFEICIENCY TOTAL		14%																	
STD DEV		9%																8%	5%

Table 6. Pre-RASP Freight Rates

Year	Quarter	HUMPHREYS	LENTHALL	DIEHL	GRUMMAN	KANAWHA	PECOS	BIG HORN	TIPPECANOE	PATUXENT	YUKON	LARAMIE	RAPPAHANNOCK	LEWIS AND CLARK	SACAGAWEA	PEARY	EARHART	SUPPLY	BRIDGE	RAINIER	2009 TOTALS	2010 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2009 Q1	1							$ 72	$ 108	$ 61				$ 182	$ 412			$ 54			$ 148	
2009 Q2	2			$ 88	$ 75			$ 77						$ 68	$ 190						$ 100	
2009 Q3	3		$ 52	$ 104	$ 138				$ 86											$ 54	$ 87	
2009 Q4	4		$ 121			$ 58			$ 95								$ 117		$ 47		$ 88	
2010 Q1	1					$ 62	$ 110			$ 61						$ 96	$ 398	$ 52				$ 130
2010 Q2	2									$ 63	$ 71	$ 66	$ 83			$ 122		$ 60				$ 78
2010 Q3	3	$ 106	$ 71					$ 74				$ 91	$ 73	$ 110		$ 90						$ 88
2010 Q4	4	$ 99		$ 91				$ 72		$ 75		$ 113		$ 102			$ 89			$ 62		$ 88
CLASS AVERAGE		86												180				53				
CLASS STD DEV		17												92				6				
AVERAGE FREIGHT RATE		$ 103	$ 81	$ 94	$ 107	$ 60	$ 110	$ 74	$ 96	$ 65	$ 71	$ 90	$ 78	$ 116	$ 301	$ 103	$ 201	$ 55	$ 47	$ 58	$ 106	$ 96
PRE-RASP FRIEGHT RATE		101																				
STD DEV		59																			$ 29	$ 23

Table 7. Post-RASP Freight Rates

Year	Quarter	HUMPHREYS	DIEHL	ERICSSON	PECOS	TIPPECANOE	PATUXENT	LARAMIE	EVERS	SHEPARD	BYRD	BRASHEAR	DREW	CHAVEZ	BRIDGE	ARCTIC	RAINIER	2013 TOTALS	2015 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2013 Q1	1	$ 99	$ 156				$ 144	$ 56		$ 152					$ 45			$ 109	
2013 Q2	2	$ 94	$ 66					$ 112	$ 151	$ 212					$ 86		$ 45	$ 109	
2013 Q3	3	$ 211				$ 129	$ 83			$ 197				$ 141		$ 44	$ 61	$ 124	
2013 Q4	4				$ 97		$ 1,019	$ 76		$ 166				$ 230		$ 62	$ 38	$ 241	
2015 Q1	1	$ 170	$ 93				$ 153	$ 139		$ 378			$ 143				$ 42		$ 160
2015 Q2	2	$ 26	$ 81	$ 127				$ 135		$ 182		$ 87	$ 195			$ 42	$ 54		$ 103
2015 Q3	3	$ 166		$ 151			$ 47			$ 212		$ 136				$ 42			$ 126
2015 Q4	4	$ 686			$ 106		$ 91	$ 149		$ 169	$ 154	$ 158				$ 39			$ 194
CLASS AVERAGE		149							166						53				
CLASS STD DEV		60							29						11				
AVERAGE FREIGHT RATE	$ 137	$ 207	$ 99	$ 139	$ 102	$ 129	$ 256	$ 111	$ 151	$ 209	$ 154	$ 127	$ 169	$ 186	$ 66	$ 46	$ 48	$ 146	$ 146
PRE-RASP FRIEGHT RATE		137																	
STD DEV		59																$ 64	$ 40

Table 8. Pre-RASP Vessel Utilization

Year	Quarter	HUMPHREYS	LENTHALL	DIEHL	GRUMMAN	KANAWHA	PECOS	BIG HORN	TIPPECANOE	PATUXENT	YUKON	LARAMIE	RAPPAHANNOCK	LEWIS AND CLARK	SACAGAWEA	PEARY	EARHART	SUPPLY	BRIDGE	RAINIER	2009 TOTALS	2010 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2009 Q1	1							19%	15%	21%				20%	5%			22%			17%	
2009 Q2	2			15%	18%			13%						36%	8%						18%	
2009 Q3	3		25%	9%	9%				16%											21%	16%	
2009 Q4	4		8%			29%			16%								23%		22%		20%	
2010 Q1	1					15%	7%			14%						25%	4%	21%				14%
2010 Q2	2									20%	19%	26%	23%			21%		16%				21%
2010 Q3	3	7%	24%					12%				27%	22%	25%		31%						21%
2010 Q4	4	8%	12%					16%		21%		16%		36%			27%		17%			19%
CLASS AVERAGE		16%												20%				20%				
CLASS STD DEV		5%												10%				1%				
EFFICIENCY TOTALS		8%	17%	12%	14%	22%	7%	15%	16%	19%	19%	23%	23%	29%	7%	26%	18%	20%	20%	21%	18%	19%
PRE-RASP EFFICIENCY TOTAL		18%																				
STD DEV		6%																			2%	3%

Table 9. Post-RASP Vessel Utilization

Year	Quarter	HUMPHREYS	DIEHL	ERICSSON	PECOS	TIPPECANOE	PATUXENT	LARAMIE	EVERS	SHEPARD	BYRD	BRASHEAR	DREW	CHAVEZ	BRIDGE	ARCTIC	RAINIER	2013 TOTALS	2015 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2013 Q1	QTR 1	10%	10%				6%	22%		23%					19%			15%	
2013 Q2	QTR 2	10%	25%					13%	21%	25%					19%		20%	19%	
2013 Q3	QTR 3	5%				14%	26%			23%				61%		25%	81%	34%	
2013 Q4	QTR 4				12%		1%	17%		13%				20%		19%	88%	24%	
2015 Q1	1	7%	12%				8%	5%		14%			14%				20%		11%
2015 Q2	2	21%	14%	11%				11%		18%		61%	15%			40%	13%		23%
2015 Q3	3	12%		10%			21%			15%		23%				29%			18%
2015 Q4	4	1%			8%		8%	6%		15%	19%	18%				24%			12%
CLASS AVERAGE		12%							25%						30%				
CLASS STD DEV		2%							10%						13%				
EFFICIENCY TOTALS		9%	15%	11%	10%	14%	12%	12%	21%	18%	19%	34%	15%	41%	19%	27%	44%	23%	16%
POST-RASP EFFEICIENCY TOTAL		20%																	
STD DEV		11%																8%	5%

Table 10. Pre-Rasp Voyage Utilization

Year	Quarter	HUMPHREYS	LENTHALL	DIEHL	GRUMMAN	KANAWHA	PECOS	BIG HORN	TIPPECANOE	PATUXENT	YUKON	LARAMIE	RAPPAHANNOCK	LEWIS AND CLARK	SACAGAWEA	PEARY	EARHART	SUPPLY	BRIDGE	RAINIER	2009 TOTALS	2010 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2009 Q1	1							54%	63%	80%				63%	50%			56%			61%	
2009 Q2	2			57%	78%			53%						63%	50%						60%	
2009 Q3	3		58%	51%	68%				50%											48%	55%	
2009 Q4	4		47%			94%			76%								71%		51%		68%	
2010 Q1	1					64%	75%			68%						66%	53%	74%				67%
2010 Q2	2									74%	81%	87%	72%			62%		52%				71%
2010 Q3	3	75%	83%					53%				71%	83%	50%		83%						71%
2010 Q4	4	58%		71%				47%		86%		50%		66%			77%			61%		65%
CLASS AVERAGE		70%												62%				55%				
CLASS STD DEV		9%												9%				5%				
EFFICIENCY TOTALS		67%	63%	60%	73%	79%	75%	52%	63%	77%	81%	69%	78%	61%	50%	70%	67%	61%	51%	55%	61%	68%
PRE-RASP EFFICIENCY TOTAL		66%																				
STD DEV		10%																			5%	3%

Table 11. Post-RASP Voyage Utilization

Year	Quarter	HUMPHREYS	DIEHL	ERICSSON	PECOS	TIPPECANOE	PATUXENT	LARAMIE	EVERS	SHEPARD	BYRD	BRASHEAR	DREW	CHAVEZ	BRIDGE	ARCTIC	RAINIER	2013 TOTALS	2015 TOTALS
CLASS		AO	AO	AO	AO	AO	AO	AO	AKE	AKE	AKE	AKE	AKE	AKE	AOE	AOE	AOE		
2013 Q1	QTR 1	66%	67%				63%	25%		58%					60%			57%	
2013 Q2	QTR 2	71%	60%					80%	71%	60%					45%		61%	64%	
2013 Q3	QTR 3	67%				54%	89%			49%				83%		70%	89%	72%	
2013 Q4	QTR 4				54%		69%	80%		48%				51%		62%	86%	64%	
2015 Q1	1	49%	65%				64%	59%		50%			80%				65%		62%
2015 Q2	2	63%	67%	52%				73%		80%		89%	68%			83%	69%		72%
2015 Q3	3	47%		52%			86%			70%		73%				54%			64%
2015 Q4	4	44%			70%		74%	64%		57%	66%		70%			73%			65%
CLASS AVERAGE		61%							69%						65%				
CLASS STD DEV		7%							7%						11%				
EFFICIENCY TOTALS		58%	65%	52%	62%	54%	74%	64%	71%	59%	66%	81%	73%	67%	53%	68%	74%	64%	65%
POST-RASP EFFEICIENCY TOTAL		65%																	
STD DEV		8%																6%	4%

IV. OBSERVATIONS AND CONCLUSIONS

The main goal of this research was to establish baseline data sets for future research in the study of increasing efficiency of CLF assets. While this was accomplished, an opportunity to analyze and draw initial conclusions should not be forsaken. This chapter discusses these observations from the analysis of the data and presents initial derived conclusions.

A. OVERALL EFFECTIVE EFFICIENCY OBSERVATIONS

The 2009 and 2010 data set, as seen in Table 4, revealed an overall effective work (OEW) of 12% and 13% with standard deviations of 2% and 3% respectively. The class averages were 12% for the AO's, 13% for the AKE's and 11% for the AOEs. Figure 11 depicts the averages broken down by individual ship over the period.

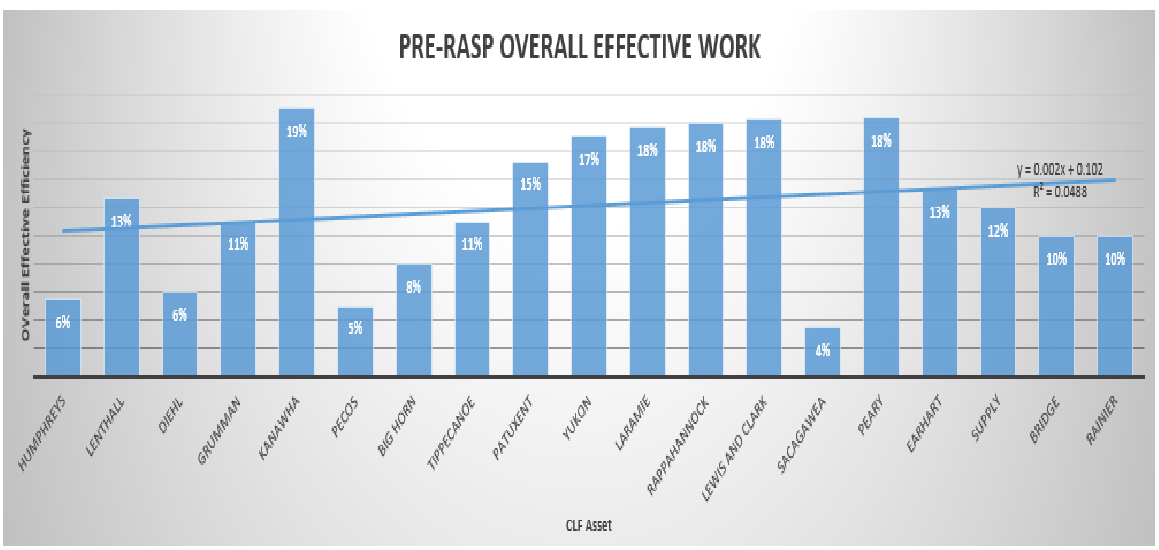


Figure 11. 2009 and 2010 OEW by CLF Asset

The 2013 and 2015 data set, as seen in Table 5, revealed an OEW of 16% and 11% with standard deviations of 8% and 5%, respectively. The class

averages were 8% for the AO's, 18% for the AKE's and 22% for the AOE's. Figure 12 depicts the averages broken down by individual ship over the period.

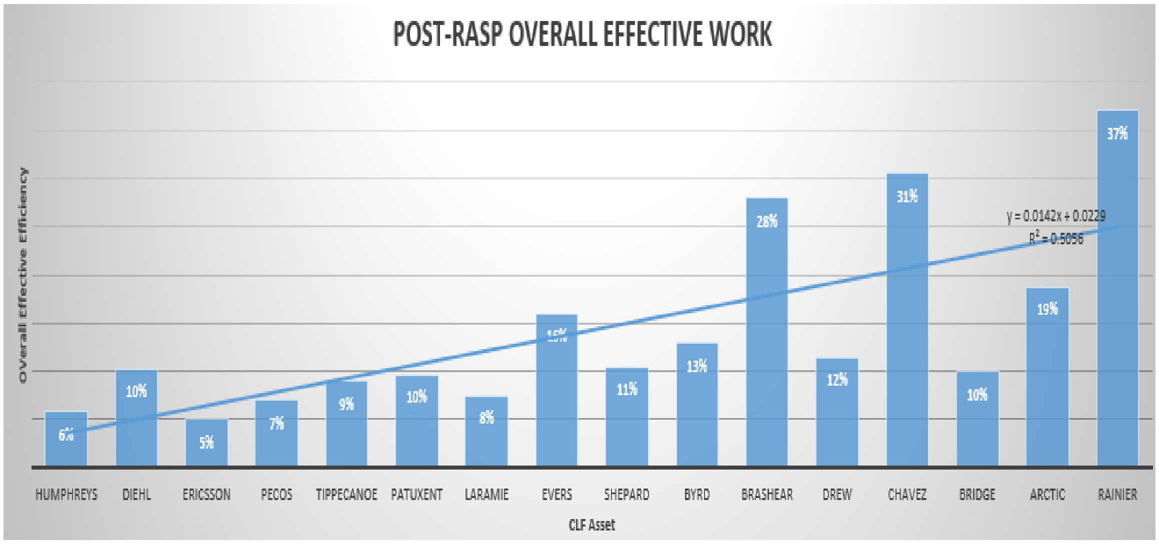


Figure 12. 2013 and 2015 OEW by CLF Asset

B. VOYAGE UTILIZATION OBSERVATIONS

Pre-RASP versus Post-RASP voyage utilization averages were effectively the same as seen in Tables 10 and 11. The 2009 and 2010 data set reveals a 66% average with a standard deviation of 10%. The 2013 and 2015 data set average was 65% with a standard deviation of 8%. The ship class averages were slightly more variable but all numbers for both sets of data fell within one standard deviation. Figures 13 and 14 depict the CLF asset averages.

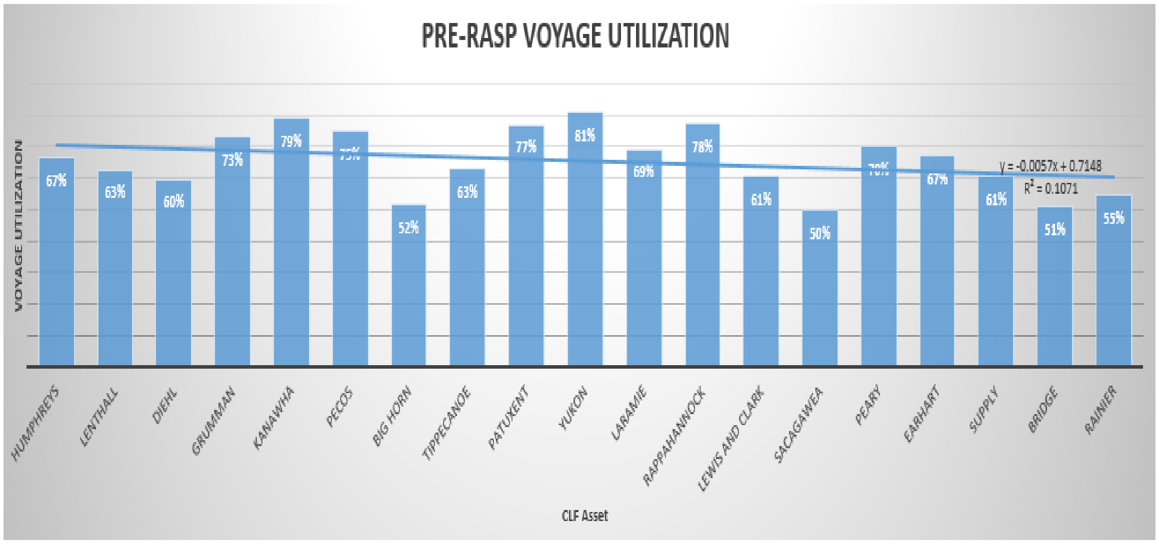


Figure 13. 2009 and 2010 Voyage Utilization by CLF Asset

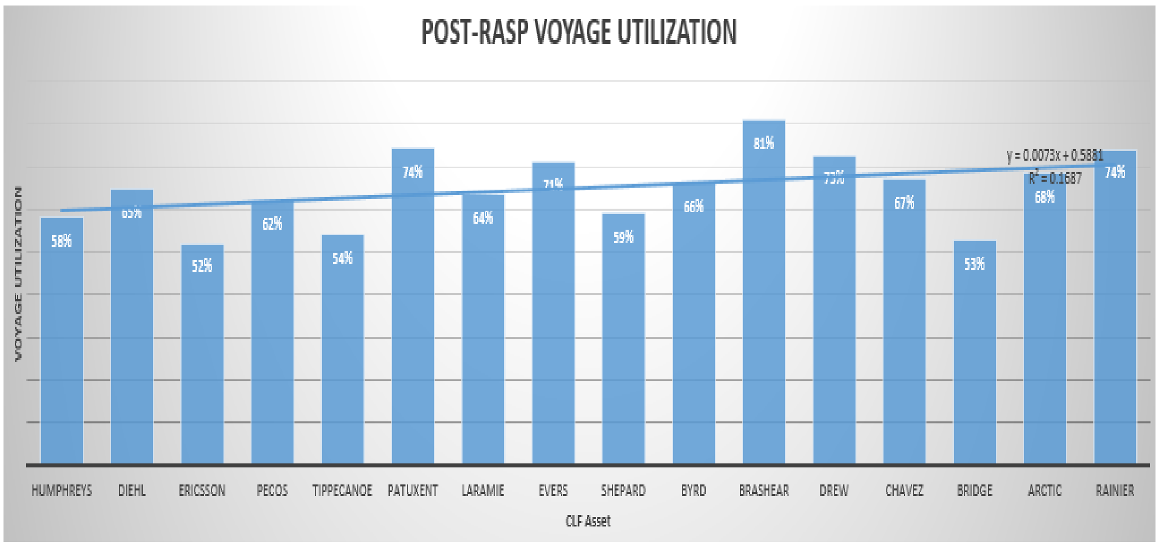


Figure 14. 2013 and 2015 Voyage Utilization by CLF Asset

C. VESSEL UTILIZATION OBSERVATIONS

Vessel utilization showed some variability between data sets as seen in Tables 8 and 9. The pre-RASP data revealed an overall average of 18% with a 6% standard deviation. The post-RASP data set averaged 20% with a standard deviation of 11%. The AO's and AKE's were roughly the same between data sets. The AOE's showed the most variation between data sets. The pre-RASP

AO average was 20% with a 1% standard deviation. The average increases 10% post-RASP to a vessel utilization of 30% and a standard deviation of 13%. This increase was mainly driven by the 81% and 88% posted by USNS *Rainier* (T-AOE-7) in 2013 quarters 3 and 4. Without these two quarters, the overall average and standard deviation would have been 21% and 5%, respectively, which are effectively the same as the pre-RASP numbers. Vessel utilization by CLF asset is shown in Figures 15 and 16.

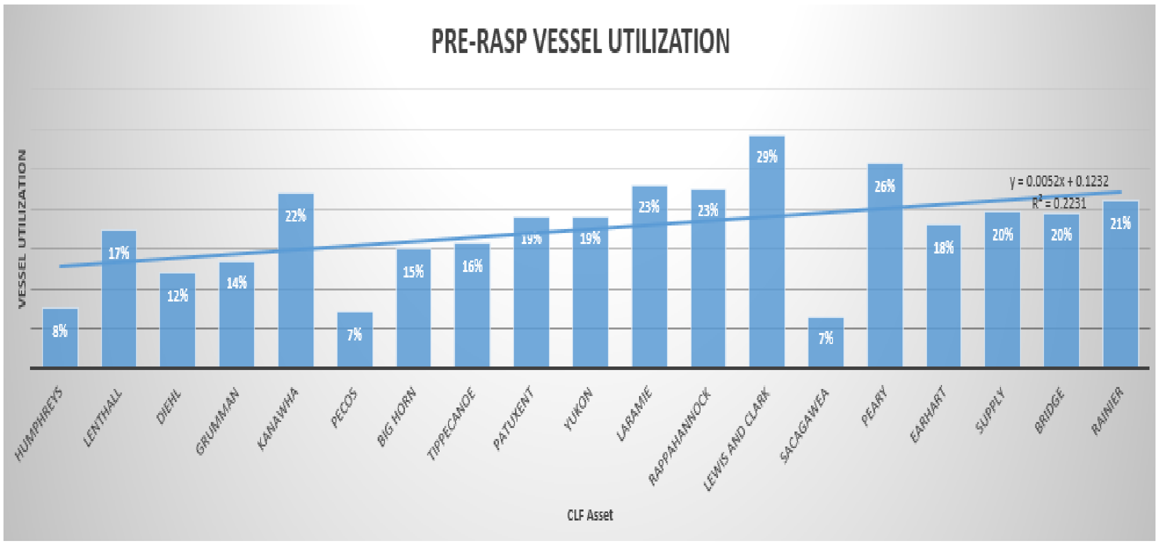


Figure 15. 2009 and 2010 Vessel Utilization by CLF Asset

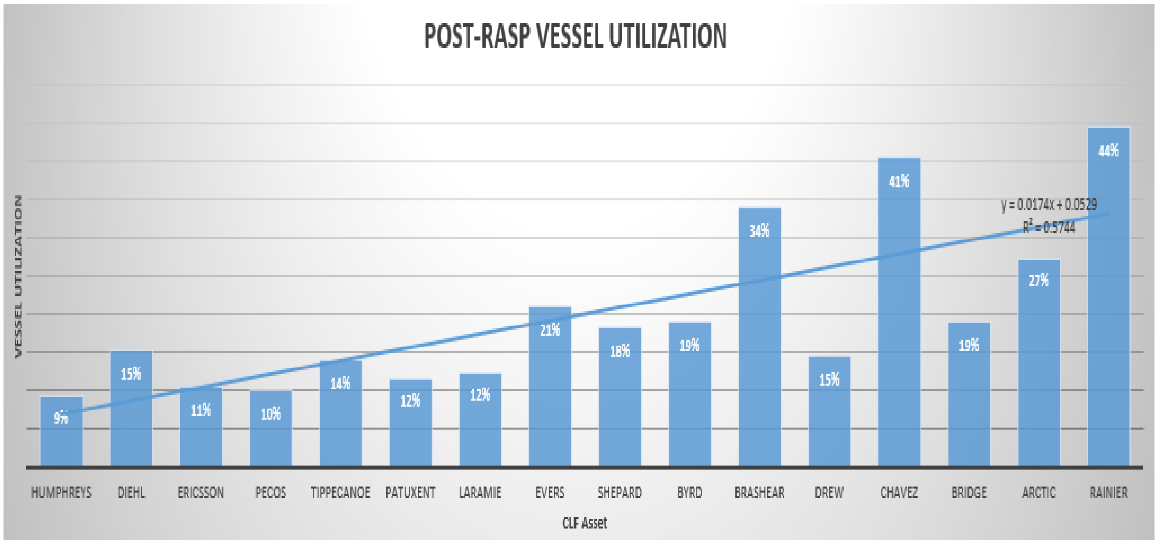


Figure 16. 2013 and 2015 Vessel Utilization by CLF Asset

D. FREIGHT RATE OBSERVATIONS

Freight rate data sets are depicted in Tables 6 and 7. 2009 and 2010 showed overall freight rate per m3 calculations of $101 with a standard deviation of $59. Post-RASP, the average freight rate was higher at $137 with a standard deviation of $59. Pre-RASP CLF asset comparisons showed an average $86 for the AO's, $180 for the AKE's, and $53 for the AOE's. 2013 and 2015 averages were $149, $156, and $53 for the AO's, AKE's, and AOE's respectively. While the AOE class averages were the same across pre- and post-RASP data sets, the telling metrics was the standard deviation. 2013 and 2015 variation was double that of the pre-RASP AOE figures. Pre- and post-RASP freight rates are depicted by individual ships in Figures 17 and 18.

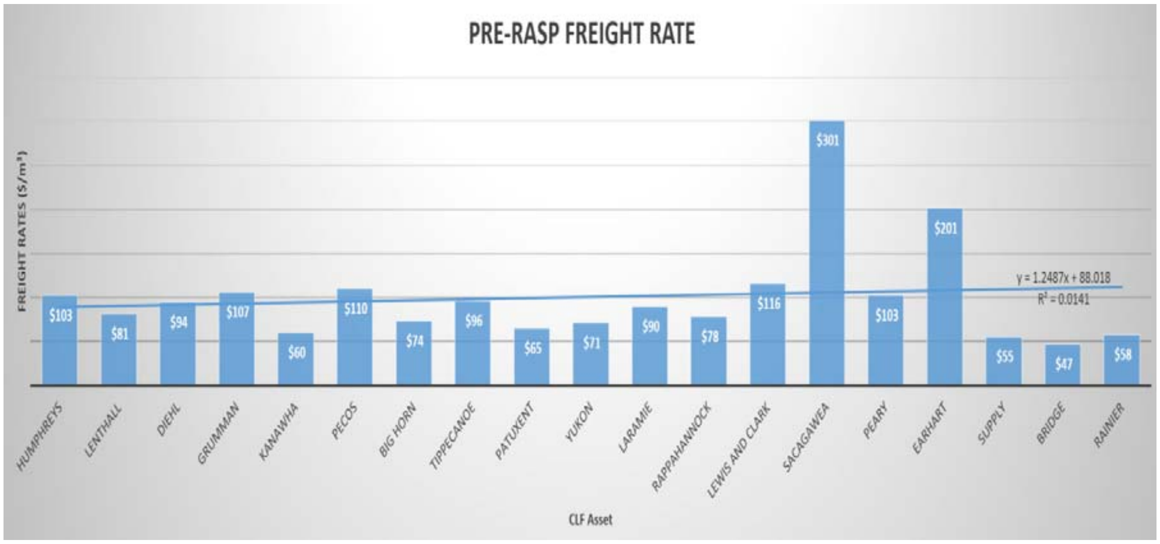


Figure 17. 2009 and 2010 Freight Rate by CLF Asset

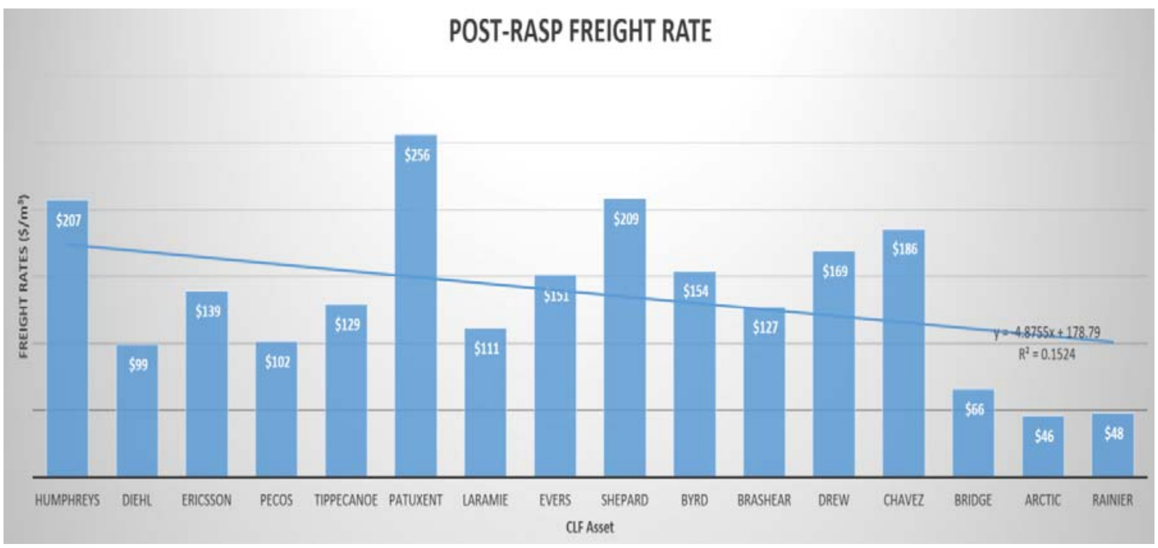


Figure 18. 2013 and 2015 Freight Rate by CLF Asset

E. SUPPLY AND DEMAND OBSERVATIONS

Total supply and demand may be seen in Figures 9 and 10 and includes both U.S. and coalition resources. Supply at 14 knots dwarfs demand by a factor of 110:1 pre-RASP and then 102:1 post-RASP. In 2009 and 2010 the average demand was 45,011 m^3 of commodity and the average supply was 4,951,291 m^3 of commodity. 2013 and 2015 averages were similar with demand at 47,116 m^3

of commodity and the average supply as 4,819,137 m^3 of commodity. The standard deviations for demand were 13,322 m^3 and supply was 39,018 m^3. Given this analysis, it may be assumed that supply and demand were equal through all quarters analyzed with minimal variation.

F. SUPPLY AND DEMAND CONSIDERATIONS

While it seems as though fewer provider ships might be able to supply the demand in the Fifth Fleet AOR based upon the supply and demand ratios, this is not necessarily the case. One must consider that every CLF asset is not capable of meeting RAS needs of every customer (due to speed restrictions, the AOE is the only asset capable of meeting the carrier strike groups massive demands). Consideration of the large distances and numerous chokepoints involved in the AOR is also important. It is roughly 1,000 nm from the North Red Sea to Djibouti, 1,400 nm from Djibouti to the North Arabian Sea, and 800 nm from the North Arabian Sea to the Northern Persian Gulf with transits through the Straights of Bab al-Mandab and the Straits of Hormuz. Remember, all of the demand is filled through RAS events. Furthermore, the time required for each port evolution, each RAS event, each non-working leg, is not captured by pure supply and demand calculations. The CLF loses capacity by each of these operational facets.

G. CONCLUSIONS

The primary goal of this research was to establish a baseline of data to support future research. This goal has been accomplished through the collection, formatting, and analysis of 2009, 2010, 2013, and 2015 supply and demand models. Trends throughout the analysis of pre- and post-RASP models were generally inconsistent. This may be attributed to the analysis of only four years' worth of data. Also, the employment of CLF assets is largely dependent upon military operations taking place as this shifts the required demand. For example, air operations will drive the demand for JP-5 on the aircraft carrier up sharply. Given the inconsistencies, there is room for preliminary analysis that may help to focus further research.

The trends in overall effective work (OEW) were sporadic between pre-RASP and post-RASP data sets. There was a slight increase to 14% from before to after RASP initialization. Quarter by quarter analysis shows an increase of efficiency during the second quarter in three of four years but there are no other observable consistencies. Figure 19 depicts the quarter over quarter model for each year.

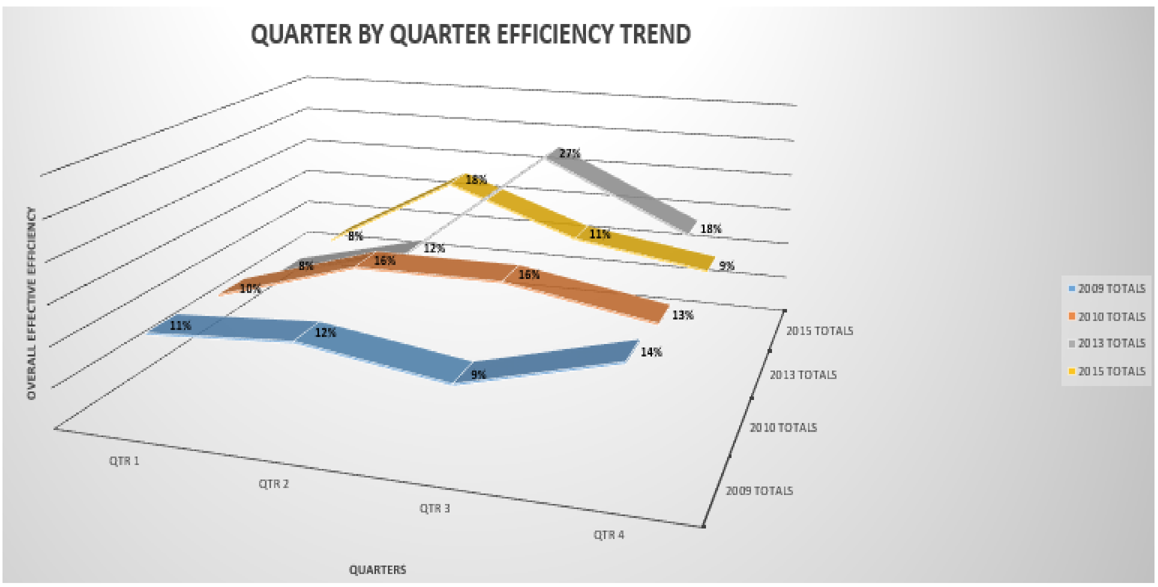


Figure 19. Quarter by Quarter Efficiency Trends

Assuming that the increase in efficiency was a legitimate increase, it is important to understand the driving factors involved. OEW has been previously defined as the product of vessel and voyage utilization. Since voyage utilization was consistent through each of the four years the conclusion is that vessel utilization was the determining factor. Vessel utilization is the total amount of commodity delivered in a voyage divided by the total commodity capacity of the CLF asset. Demand is finite in the AOR so it would seem that the efficiency is driven by the class of vessel used to meet the demand. Based on the data, the AOE is both the most efficient asset and has the lowest freight rates. The

problem is that there are a limited number of AOE's available and there is significant capital invested in the other classes of supply ships.

This is where scheduling efficiency become important. It is imperative that the use and scheduling of the other CLF assets is handled with fiscal responsibility. There are examples of voyages involving AO’s and AKE’s that show OEW and freight rates comparable to those of their AOE counterparts. *USNS Lenthall* (TAO-189) posted several voyages in 2009 that may serve as an example as depicted in Tables 12 and 13.

Table 12. USNS *Lenthall* (TAO-198) 2009 Quarter 3 Voyage Example 1

UNREP_ID	DateofSvc	Ship_Port_Serviced	TOTAL XFR M^3	DISTANCE TRAVELED WORK	DISTANCE TRAVELED NON-WORK	TOTAL VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK	PORT COSTS	DAYS @ SEA	TOTAL FUEL CONSUMED (GAL)	VOYAGE COSTS (14 KNTS)	TOTAL COSTS	FREIGHT COSTS (PER M^3)
23769	8/7/2009	DJIBOUTI													
23479	8/8/2009	LENTHALL													
25539	8/8/2009	LABOON		577											
23770	8/9/2009	CORNWALL													
R9220	8/9/2009	JOHN PAUL JONES													
23771	8/10/2009	GEDIZ													
24282	8/10/2009	MUMBAI													
25540	8/10/2009	JAMES E WILLIAMS													
26866	8/13/2009	BAINBRIDGE		699											
23501	8/15/2009	LENTHALL													
24283	8/16/2009	GEDIZ													
24284	8/16/2009	GAZIANTEP													
24285	8/17/2009	JACOUBET		699											
24286	8/17/2009	MUMBAI													
24287	8/18/2009	LIBECCIO													
24288	8/18/2009	DAEJOYUNG													
24289	8/18/2009	LA FAYETTE													
24290	8/18/2009	BREMEN													
25782	8/18/2009	DONALD COOK													
VOYAGE TOTALS			6916	1975	577	2552	24%	77%	18%	$ 37,247	13	217750	$ 428,968	$ 466,215	$ 67

Table 13. USNS *Lenthall* (TAO-198) 2009 Quarter 3 Voyage Example 2

UNREP_ID	DateofSvc	Ship_Port_Serviced	TOTAL XFR M^3	DISTANCE TRAVELED WORK	DISTANCE TRAVELED NON-WORK	TOTAL VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK	PORT COSTS	DAYS @ SEA	TOTAL FUEL CONSUMED (GAL)	VOYAGE COSTS (14 KNTS)	TOTAL COSTS	FREIGHT COSTS (PER M^3)
24192	8/20/2009	DJIBOUTI													
24291	8/21/2009	DJIBOUTI													
24292	8/22/2009	NAVARINON		577											
24293	8/22/2009	ANZIO													
26867	8/23/2009	DONALD COOK													
24294	8/23/2009	EVERTSEN													
24295	8/23/2009	FRIDTJOF NANSEN													
24296	8/23/2009	BREMEN													
24297	8/23/2009	LIBECCIO													
25783	8/23/2009	HOWARD													
23502	8/24/2009	LENTHALL													
25784	8/25/2009	ARLEIGH BURKE													
24298	8/26/2009	GAZIANTEP													
25785	8/26/2009	CHANCELLORSVILLE													
25786	8/27/2009	JAMES E WILLIAMS		699											
25787	8/27/2009	BAINBRIDGE													
24299	8/28/2009	BRANDENBURG		699											
24300	8/28/2009	LA FAYETTE													
25788	8/29/2009	HOWARD													
24301	8/29/2009	FRIDTJOF NANSEN													
25789	8/30/2009	BAINBRIDGE													
24302	9/2/2009	DAEJOYUNG													
24303	9/2/2009	CANARIAS													
24304	9/2/2009	NAVARINON													
25790	9/3/2009	ANZIO													
24305	9/3/2009	MUMBAI													
24306	9/3/2009	THACH													
VOYAGE TOTALS			10971	1975	577	2552	38%	77%	29%	$ 37,247	14	234500	$ 461,965	$ 499,212	$ 46

In both of the above examples, USNS *Lenthall* (TAO-189) delivers high amounts of commodity while ensuring above average vessel utilization and voyage utilization. These examples seem to be outliers for the AO but a change in the way that schedulers organize the voyages could make these types of numbers more normal. Based upon this research, scheduling longer voyages that deliver larger total amounts of commodity will produce better results than shorter voyages that deliver small amounts. In doing so, the schedulers could bring real savings and fiscal maturity in the use of CLF assets. These savings would come from reduced fuel and underway costs for MSC as well as reducing the cost of transporting a cubic meter of commodity per nautical mile, which is the definition of the freight rate metric. While all of this assumes a pure logistical model, the reality is that the CLF is responsible for ensuring that the customer can meet its mission objectives, many of which are high priority, where maximum operational capacity is more important than efficiency.

The freight rate metric serves as another barometer to effective scheduling efficiency. As previously mentioned, the AOE boasts consistently lower freight rates than the other classes and there appears to be several reasons for this. First, recall that the station vs shuttle ship concept uses the AOE as the on station ship with the carrier strike group. While the data suggests that the Fifth Fleet AOR trends away from this concept, there are examples of exceptional freight rates, vessel, and voyage utilization when the concept is put into practice. *USNS Rainier's* (TAOE-7) 2013 Quarter 3 voyages are an example of exceptional scheduling efficiency and are depicted in Tables 14 and 15.

Table 14. USNS *Rainier's* (TAOE-7) 2013 Quarter 3 Voyage #1

UNREP_ID	DateofSvc	Ship_Port_Serviced	M.Port	TOTAL XFR M^3	DISTANCE TRAVELED **WORK**	DISTANCE TRAVELED **NON-WORK**	**TOTAL** VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK	PORT COSTS	DAYS @ SEA	TOTAL FUEL CONSUMED (GAL)	VOYAGE COSTS (14 KNTS)	TOTAL COSTS	FREIGHT COSTS (PER M^3)
35325	6/30/2013	FUJAIRAH	0													
36251	7/3/2013	CARTER HALL	626		626											
36252	7/5/2013	RAINIER	CHENG													
36253	7/7/2013	KENT	610		1437											
36254	7/9/2013	KEARSARGE	935		325											
36255	7/9/2013	SAN ANTONIO	935													
36256	7/10/2013	RAINIER	CHENG													
36257	7/12/2013	NEWCASTLE	610		325											
36258	7/17/2013	PRINCETON	397		1926											
36259	7/17/2013	TIPPU SULTAN	397													
36260	7/19/2013	NEWCASTLE	130		267											
R26030	8/26/2013	FRIDTJOF NANSEN	397		267											
36261	7/20/2013	NIMITZ	397													
36262	7/20/2013	DRAGON	397													
36263	7/20/2013	PRINCETON	397													
36264	7/22/2013	HUMPHREYS	CONSOL													
36265	7/23/2013	WILLIAM P LAWRENCE	227		715											
36266	7/23/2013	MONTEREY	227													
36267	8/7/2013	TIPPECANOE	CONSOL													
36268	8/8/2013	NIMITZ	60		169											
36269	8/8/2013	DRAGON	60													
36270	8/9/2013	RAINIER	CHENG													
VOYAGE TOTALS				**26683**	**6057**	**248**	**6305**	**100%**	**96%**	**96%**	**$ 63,815**	**43**	**720250**	**$ 1,418,893**	**$ 1,482,708**	**$ 56**

Table 15. USNS *Rainier's* (TAOE-7) 2013 Quarter 3 Voyage #2

UNREP_ID	DateofSvc	Ship_Port_Serviced	M.Port	TOTAL XFR M³	DISTANCE TRAVELED WORK	DISTANCE TRAVELED NON-WORK	TOTAL VOYAGE DISTANCE	VESSEL UTILIZATION	VOYAGE UTILIZATION	OVERALL EFFECTIVE WORK	PORT COSTS	DAYS @ SEA	TOTAL FUEL CONSUMED (GAL)	VOYAGE COSTS (14 KNTS)	TOTAL COSTS	FREIGHT COSTS (PER M³)
36271	8/12/2013	FUJAIRAH	0													
36272	8/14/2013	DRAGON	60		248											
36273	8/15/2013	RAINIER	CHENG													
36274	8/24/2013	TORONTO	130		323											
36275	8/24/2013	STOCKDALE	130													
36276	8/26/2013	NIMITZ	397													
36277	8/26/2013	PRINCETON	397		267											
36278	8/27/2013	CHAVEZ	CONSOL													
36279	8/28/2013	STOCKDALE	397													
36280	8/28/2013	PRINCETON	397													
36281	8/28/2013	SHOUP	397													
36282	8/28/2013	WILLIAM P LAWRENCE	397													
36283	9/1/2013	PERRY	397													
36284	9/3/2013	RAINIER	CHENG													
36285	9/4/2013	RAINIER	CHENG													
36286	9/9/2013	NIMITZ	610		1926											
36287	9/9/2013	PRINCETON	610													
36288	9/9/2013	STOCKDALE	610													
36289	9/9/2013	SHOUP	610													
36290	9/9/2013	WILLIAM P LAWRENCE	610													
VOYAGE TOTALS				16271	2764	610	3374	61%	82%	50%	$ 63,815	33	552750	$ 1,088,918	$ 1,152,733	$ 71
2013 QTR 3 TOTALS				42954	8821	858	9679	81%	89%	73%	$ 127,630	76	1273000	$ 2,507,810	$ 2,635,440	$ 61

USNS *Rainier* (TAOE-7) is able to remain on station for 43 and 33 days respectively thanks to refueling by the stations ships USNS *Humphreys* (TAO-188), USNS *Tippecanoe* (TAO-199), and USNS *Chavez* (TAKE-14). Next, being the only CLF asset that can maintain speeds allowing it to keep with the aircraft carrier make it the asset of choice to refuel the USS *Nimitz* (CVN-68) carrier strike group during this period. This provides a dedicated source of very high demand unique to the AOE. It should be noted, however, that these voyages could possibly be classified as high priority vice purely logistical as the they were in support of operations in Syria (Shalal-Esra, 2013).

The final conclusion is that coalition partners add an immense amount of supply and demand to the Fifth Fleet AOR. The coalition ships in theater add about 20% demand and 30% supply through all periods analyzed. The latter relieves American assets operationally and logistically. Figures 20 and 21 depict raw supply and demand percentages for both pre- and post-RASP.

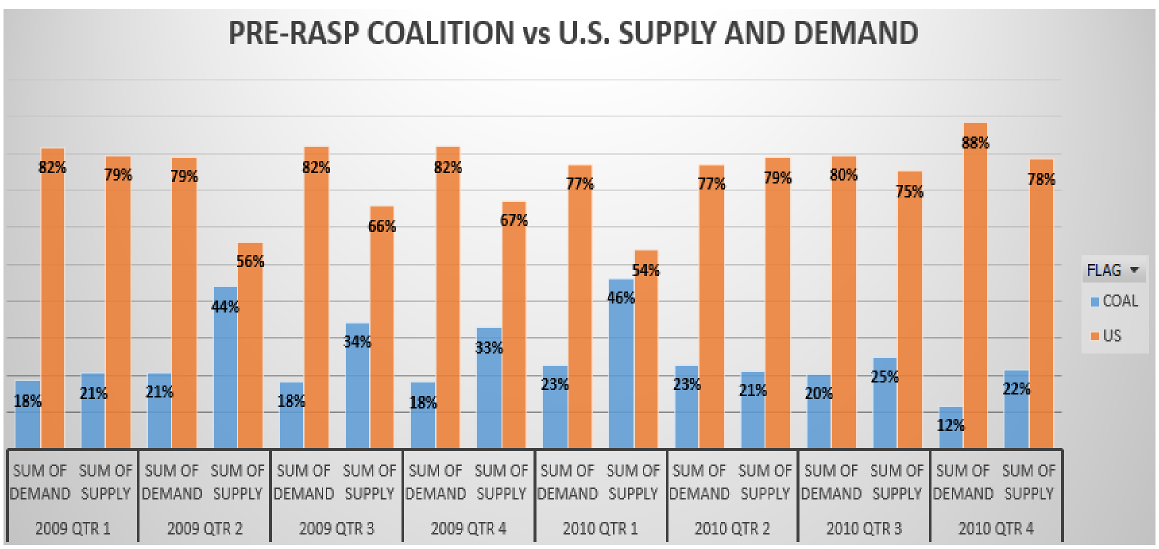


Figure 20. Pre-RASP Coalition Supply and Demand

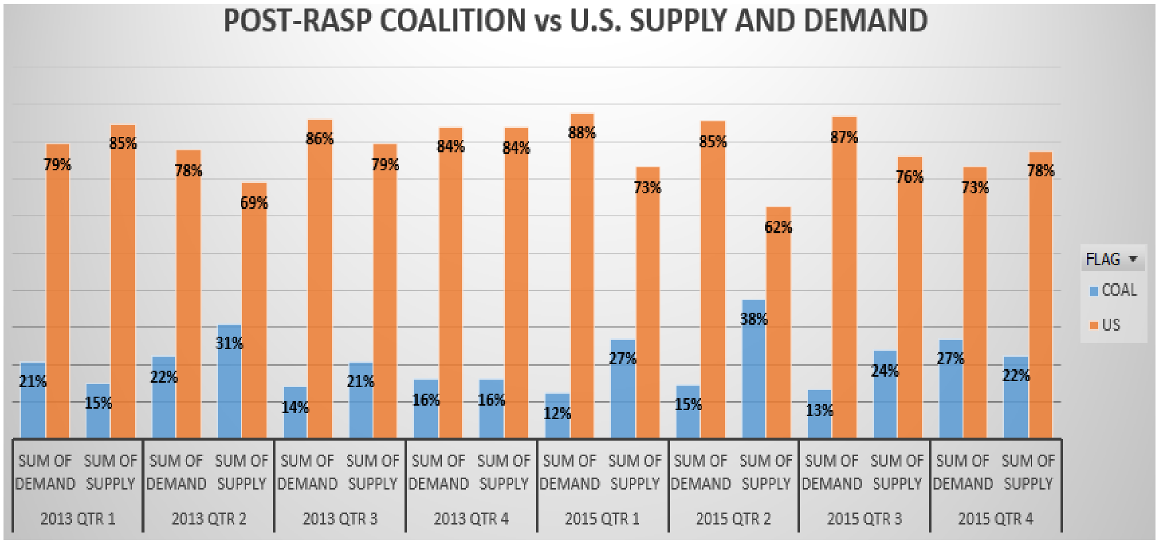


Figure 21. Post-RASP Coalition Supply and Demand

V. RECOMMENDATIONS AND FUTURE RESEARCH

Given the inconclusiveness of the trends encountered in the data sets, further research is required. The recommendation is to compile, format, and analyze data from 2011-2013 to fill out the pre-RASP data and conduct the same for 2014 and 2016 for the post-RASP data. 2011 has already been compiled and will be included with all forwarded data from this research.

Furthermore, there is opportunity for more detailed cost information for the CLF voyage periods. Port costs were given a standard rate based upon the average port cost found in the LogSSR database but the number of days in port was not calculated. As port costs can potentially have important impacts, future research should focus on this aspect. The freight rates proposed in my research are most likely lower than those that include more detailed cost information. The same is true for underway CLF costs. Fuel costs were the only cost factors analyzed for underway periods. Maintenance, personnel, food, and consumable expenses increase the costs of CLF asset's underway periods. Again, this data was not considered in my research and likely resulted in lower freight rates. The final cost factor that may impact the trends would be fuel costs. This study used a standard rate for fuel in order to normalize data across the wide range of periods analyzed and did not normalize for inflation. Using actual fuel costs and normalizing for a base year inflation will improve the cost calculations found in this research.

A better understanding of the impacts and benefits that coalition partners bring to the Fifth Fleet AOR is required. Discussions with schedulers have revealed that scheduling and coordinating with these ships is difficult at best. Data for coalition CLF assets was not as accurate as those in the U.S. inventory. This is why I was unable to include efficiency data and freight rate information for coalition supply ships in my data. The data showing when, where, and the amount of commodity transferred for coalition RAS events was accurate but most of their port call information was missing. Without this, the specific

voyage periods to perform the required calculations could not be defined. The recommendation is to better assimilate this data.

RASP is an excellent tool that has great potential in the optimization of logistics support in the Fifth Fleet AOR. While this study's data shows minimal increase in efficiency at best, further research may provide different results. RASP affords an opportunity to collect and disseminate cumbersome data that was previously difficult to obtain. There are also intangible benefits the RASP brings to the table such as decreasing the work load on the schedulers, freeing them for other work. This increase in time allows for better coordination and communication with individual supply officers aboard ships and increases the scheduler's understanding of the customer's needs.

While we place immense focus on operating CLF assets in the most efficient manner possible, the CLF is only but a subsystem in the overall Department of Defense system. Joint Publication 4-0 states that the imperatives of joint logistics are unity of effort, visibility and common processes, and rapid and precise response (Department of Defense [DOD], pp. I 8-9, 2013). Efficiency is only a small subset of a policy that values speed and reliability above all else. This is not wrong per se, but as the U.S. Navy shifts away from combat operations and into "presence" type missions, the mindset must shift as well, especially in times of fiscal uncertainty. There is a time for high op-tempo logistics that ensures the warfighter is ready and capable to bring the strength of the military arm to bear and we have proven that we are effective at that. There is also a time for fiscally minded efficient operations that resemble our commercial counterparts. It is here that the CLF must improve and RASP may be the tool to influence this shift.

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